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ABSTRACT

The purpose of this research project is to specify critical events within a person during linguistic processing. The experiments reported here cover such topics as the effects of increased reading rate on covert processes, covert behavior as a direct electro-myographic measure of mediating responses, enhancement of speech perception by simultaneous reading, external auditory feedback from covert oral behavior during silent reading, evoked potentials to auditory stimuli, covert psychophysiological responses and language processing, covert linguistic behavior in deaf subjects during thinking, electrical measurements of neuromuscular states during mental activity, covert oral behavior during conversational and visual dreams, and the function of covert oral behavior ("silent speech") during silent reading. Details on each experiment are provided. Figures and tables help to illustrate the results. A list of references is included. (VM)

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Final Report

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COVERT RESPONSE PATTERNS IN PROCESSING LANGUAGE STIMULI

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Author's Abstract

A series of experiments was conducted to specify critical events within a person during linguistic processing. Among the conclusions were: 1) increased reading rate increased covert oral behavior (tongue electromyograms); 2) tongue electromyograms were relatively heightened for subjects engaged in verbal mediation; 3) unclear auditory information was perceptually clarified with synonomous visual input, and was correlated with heightened tongue electromyograms; 4) feedback from covert oral behavior during silent reading only temporarily depressed covert oral behavior; 5) we failed to find common events among individuals during speech perception; 6) manual and oral regions of deaf subjects covertly functioned during thinking; 7) the bodily region that would be active during overt performance of a task was covertly active while imagining performance of the task; 8) covert oral behavior was heightened during conversational night dreams but not during visual dreams; 9) relevant research indicated that covert oral behavior is beneficial during silent reading. In conclusion, covert oral and non-oral responses are intimately involved in internal linguistic processing. Perhaps as components of feedback loops they generate verbal codes that integrate central and peripheral linguistic regions.

Project Overview

The purpose of this research project was to specify critical events within a person during linguistic processing. Results of experiments conducted to accomplish each of six objectives that were specified, and two more added later, are as follows. 1) To assess the effects of increased reading rate on covert processes, three experiments were conducted using children and adults. Among the results was an apparent increase in amplitude of tongue electromyograms, suggesting that heightened covert oral behavior facilitates the reading process. 2a) A verbal mediational paradigm was used to attempt to directly measure mediating responses in an experimental group, relative to covert behavior of two control groups. Tongue electromyograms significantly increased from before to after mediation only for the verbal mediation group, the increase being significantly greater than for the two control groups. These and other psychophysiological measures of covert behavior during mediation were consistent with verbal mediational theory based on the study of overt behavior. 2b) In a mediational study related to Osgood's r_m, we investigated the possible facilitation of linguistic information entering through one modality as a result of the same information from another modality. An experiment was conducted as follows. When orally presented information was unclear, it was found that that information became perceptually clarified in the auditory modality if the same information was input visually. Hence, presentation of synonomous material in one communication modality can clarify perception in another modality. Correlated with the perceptual clarification was heightened tongue EMG, suggesting that covert oral feedback might have facilitated the clarification, indicating a possibly valuable function of the covert oral response. 3) To attempt to assess the effect of external auditory feedback from covert oral behavior during silent reading, it was found that feedback did reduce amplitude of the controlling and associated speech muscles. However, withdrawal of feedback returned the muscle amplitude to about baseline level indicating that the reduction in covert oral behavior was not permanent; rather, it was dependent on the feedback stimulus. Hence, more effective controlling techniques are required before we can stringently determine the function of the covert oral response with this approach. 4) To study events within us as we perceive spoken language, a variety of psychophysiological events were recorded in very young children as they perceived distinctive linguistic stimuli. We failed to find relatively heightened lip activity associated with the presentation of labials, though several other findings of some interest are discussed. 5) In the study of covert linguistic behavior in deaf subjects during thinkir Max's classical experiments were replicated. It was found that amplitude of left arm and lip electromyograms significantly increased during problem solving. Hence, in conformity with the findings of Max, it was concluded that the manual and oral regions were covertly functioning as a single linguistic system during thinking. 6) Objective 6 was an attempt to replicate Jacobson's classical work on electrical measurement of neural muscular states during mental activity. With normal awake subjects there was some hint that the bodily region for the relevant imagination tasks was more active, as Jacobson found. However, the effect showed up more clearly with hypnotized subjects who were better relaxed. It was concluded that our normal awake subjects were not as well relaxed as were Jacobson's but that Jacobson's findings were generally confirmed with our better relaxed subjects.

In two additional objectives that were undertaken it was found that 7) Covert oral behavior was significantly heightened during conversational night dreams but not during visual dreams; and 8) relevant research that has been conducted to assess the function of covert oral behavior during silent reading suggests that the covert oral response facilitates reading proficiency -- it is hypothesized that visually received prose are conditional stimuli that evoke conditional speech muscle activity which in turn generates a verbal code. The code, it is further hypothesized is neurally transmitted to the brain to facilitate integration of the various central language regions. These central-peripheral events thus function as components of extensive and numerous feedback loops that internally process information.

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EFFECTS OF INCREASED READING RATE ON COVERT PROCESSES

Abstract

Three experiments, one with adults and two with children, were conducted to determine whether increasing reading rate affects covert oral behavior, and other covert processes. Previous findings were confirmed that during silent reading there is heightened covert oral behavior, increased respiration rate and decreased EEG amplitude, and there was essentially no change in leg EMG or pulse rate. Increased reading rate produced a decrease in end of line eye movements (indicating that the subjects learned to read more than one line at a time) and apparently increased amplitude of tongue EMG; the increased covert oral behavior as a result of increased reading rate was more apparent in adults than in children. Perhaps heightened covert oral behavior facilitates the reading process.

EFFECTS OF INCREASED READING RATE ON COVERT PROCESSES

The majority view of the function of "subvocalization" during silent reading has been that it is detrimental to reading proficiency, e.g., Betts (1950) has stated that "...any observable form of vocalization -- such as silent lip movement...retards the rate of silent reading (which) has been common professional knowledge since the early scientific studies of reading" (p. 450). Wood's (1966) similar position is a more contemporary example. One implication of this position is that the reduction of subvocalization should result in increased reading proficiency. Efforts have been made to test this hypothesis by reducing amplitude of covert oral behavior through feedback techniques (e.g., McGuigan, 1966). Another implication is that by increasing one's reading rate, amplitude of covert oral behavior during reading should decrease.

An alternative view of the function of covert oral behavior during silent reading is that the response is beneficial (c.f., Schilling, 1929). Edfeldt (1960) holds that silent speech (as measured by electromyograms from the speech musculature) occurs in all individuals and it is likely that "... silent speech actually constitutes an aid toward better reading comprehension" (p. 154). McGuigan and Rodier (1968) also concluded that covert oral behavior during silent reading is beneficial. The hypothesis that covert oral behavior facilitates the reading process thus leads to a prediction contrary to that of the majority position, viz., that an increase in reading rate should not reduce the amplitude of a person's covert oral responses; it is even possible that increases in reading rate would result in increased amplitude of covert oral behavior. It was the purpose of this experiment to obtain data relevant to the issue specified by the two above cited interpretations of the function of covert oral behavior during reading. For this, reading rate of students was increased and the effect on the amplitude of their covert behavior was studied.

While the issue as stated has implications for theories of thinking (c.f., McGuigan, 1966) as well as technological implications for the teaching of reading, it is also important from the point of view of internal information processing. Why, for instance, do we achieve relatively uniform rates for reading, listening to speech, etc.? Is there some kind of psychological limit in linguistic processing? By studying muscular and neural events as a function of rate of linguistic input, we might find that our "standard" rates can be greatly increased, or that comprehension deteriorates once the body's built-in processing limit is reached.

Method

Subjects. For Experiment I, undergraduate female students at Hollins College volunteered to take a "Speed Reading" course and were randomly assigned to one of three groups: 17 subjects served in the Experimental Group, 6 in Control Group #1 and 7 in Control Group #2.

For Experiments II and III, male and female students from grades 8 through 12 in the Roanoke, Virginia public schools volunteered to serve as subjects and were randomly assigned to the Experimental Group and to Control Group #1. (Control Group #2 was dropped for Experiments II and III). For Experiment II, 18 subjects were in the Experimental Group, and 12 in the Control Group. For Experiment III, 22 subjects were in the Experimental Group and 12 in the Control Group.

Procedure. All subjects were first administered one form of the Nelson-Denny Reading Test, 1960 edition. For Experiment I, members of Groups E and C_1 individually rested, read silently, and rested again in the laboratory while electromyograms (EMG) were recorded from the tongue, lips, throat, and leg. Additional signals recorded were bipolar electroencephalograms (EEG) from the occipital lobes (O_1 and O_2), eye activity from the external canthi, and pneumograms.

Group E was then given a reading rate improvement course using the Science Research Associate's (SRA) accelerator and standard SRA procedures. The subjects read daily from light material of their own choosing. The accelerator setting was individually determined on the basis of a timed rate and comprehension test using SRA IVa Blue Booklets.

At the end of the reading course, all subjects from the three groups were given an alternative form of the Nelson-Denny Reading Test and were individually tested in the laboratory with the same electrode placements as for the first laboratory reading session. The EMG and EEG data were recorded on a multi-channel tape recorder, converted to mean integrated amplitudes for each 10-sec. period of relaxation and reading, digitized, and printed out. For further details of the laboratory and recording and quantification techniques, see McGuigan and Rodier (1968).

Pneumograms were quantified by counting number of respirations per minute during reading and rest. Eye activity was quantified as follows: when, during reading, subjects reached the end of a line of prose, a large spike occurs in their electrical records as they return their eyes to the left of the page to read the next line of prose (see Fig. 1). The number of these spikes during reading was counted for each subject, and divided by the number of lines read. The ratio thus computed indicated mean number of "end of line" (EOL) eye movements, per line of prose read.

Results and Discussion

Table 1 shows that the experimental subjects significantly increased their reading rate in all three experiments, as measured by the Nelson-Denny Reading Test, and in the laboratory while the psychophysiological measures were being taken. All mean differences were tested by t tests, with $\alpha = .05$. The reading rate changes for the control groups were minor and not significant. In all three experiments, the mean increase in

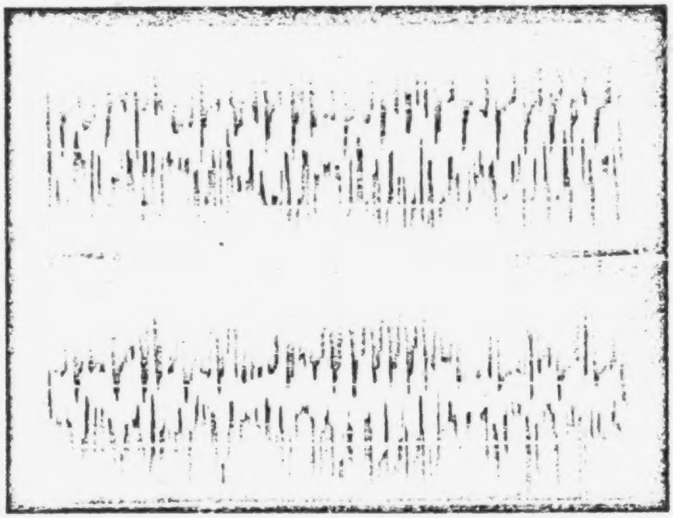

Figure 1. Sample Record of Eye Activity During Silent Reading for an Experimental Subject. Pretest record is upper trace and post-test record is lower trace. The large spikes indicate movement of the eye from the end of a line of prose to the start of the next line.

Table 1

Mean Reading Proficiency Changes

		Experiment 1			Experiment II			Experiment III		
Measure	Group	Pretest	Postest	Diff.	Pretest	Postest	Diff.	Pretest	Postest	Diff.
Nelson-Denny										
Rate (WPM)	E	332	481	149*	217	389	172*	250	470	220*
	C	397	412	15	229	230	1	203	231	28
% Comprehension	E	87	85	-2	71	68	-3	63	57	-6
	C	82	84	2	70	69	-1	57	61	4
Laboratory										
Rate (WPM)	E	361	506	145*	191	362	171*	261	480	219*
	C	419	344	-75	183	218	35	250	257	7
% Comprehension	E	62	66	4	72	75	3	64	58	-6
	C	63	65	2	74	75	1	64	63	-1
Eye Move-	E	1.008	.855	-.153*	1.002	.827	-.175*	.974	.802	-.172*
ments/line	C	1.000	1.200	.200	1.011	.992	-.019	.985	.984	-.001

*p < .05

reading rate for the Experimental Group was significantly greater than the change for the corresponding Control Group on both the Nelson-Denny and in the laboratory. In Experiment I, the increase in reading rate on the Nelson-Denny for Group E was significantly greater than for Group C #2 (t = 3.46; the mean pre-test and post-test rates for Group C#2 were 294 wpm and 315 wpm, with comprehensive scores of 85% and 86%). Changes on the Nelson-Denny were not significantly different for the two control groups. Comprehension scores generally remained rather stable for all groups.

In Table 1, it can also be seen that the experimental groups always significantly decreased the number of the EOL eye movements, and that the changes for the control groups were minor and non-significant. Furthermore, the changes in each experiment for the experimental groups were always significantly greater than for the control groups. In Experiment I, Control Group #1 made significantly more EOL movements on the second test than did Group E (t = 3.52). The values for Control Group #2 on the pre-test and post-test were .970 and .970. The facts that all three groups had essentially the same number of these EOL eye responses on their first test, and that only Group E significantly decreased the number of them during the second test, indicates that this change was produced by the reading improvement course. To consider the reason for this decrease, we may examine a typical set of tracings for an experimental subject (Fig. 1). We may note that there was no noticeable reduction in amplitude from before to after the course. One suspicion is that the subjects, as a result of the special training, learned to process more than one line at a time. Informal conversations with several subjects confirmed this: When asked how their reading had changed, they volunteered that they now often read more than one line at a time. In short, these psychophysiological measures confirm that the reading course was effective in increasing reading rate. Further, this electrical technique, easy to use, probably provides a more objective method for measuring reading rate than the standard one by reading test. And certainly it is more sensitive, in that highly refined measurements are obtained with each return of the eyes to the next line of prose to be read.

Means were computed for each subject for each psychophysiological measure during rest and during silent reading; rest values were then subtracted from reading values. Group means of these changes from resting to reading were then entered in Table 2 for both pre-test and post-test sessions. By examining the values for tongue and lip EMG as measures of covert oral behavior, we can note that in 21 of 24 instances, these variables increased in amplitude during silent reading; in no case was there a decrease. These findings typically contrast with changes for leg EMG. In general, then, the results conform with previous findings that covert oral behavior increases during silent reading, and that the increase does not seem to be merely an aspect of heightened arousal.

Mean respiration rate increased during silent reading (with the one inexplicable exception during Experiment III), a finding reported many times (e.g, McGuigan & Rodier, 1968). Similarly, previous reports of a mean integrated EEG decrease during "mental activity" were confirmed. For Experiment III peripheral pulse rate (measured from the right index finger) was substituted for the EEG channel. It was found that only minor and non-significant changes occurred for this measure, again indicating that there was no heightened state of bodily arousal that could account for the increased covert oral behavior during silent reading.

To study changes from before to after the reading course, mean differences between pre-test and post-test values were entered in the

Table 2

Mean Response Changes From Rest to Silent Reading

As a Function of Condition

Response		Experiment 1			Experiment II			Experiment III		
Measure	Group	Pretest	Postest	Diff.	Pretest	Postest	Diff.	Pretest	Postest	Diff.
Tongue EMG	E	0.0	.4	.4*	.6*	1.0*	.4	.3	.5	.2
	C	.5*	.1	-.4	1.4	1.1	-.3	.2	0.0	-.2
Lip EMG	E	.8*	.6*	-.2	.2	.4*	.2	.2	.3	.1
	C	.7	1.0*	.3	.5	1.0	.5	.2	0.0	-.2
Throat EMG	E	.1	.1	0.0	-.1	.0	.1	0.0	0.0	0.0
	C	0.0	0.0	0.0	-.3	.1	.4	0.0	0.0	0.0
Leg EMG	E	0.0	-.1	-.1	.2*	.1	-.1	.1	.0	-.1
	C	0.0	-.1	-.1	.1	-.4	-.5	-.2	.1	.3
Respiration	E	2.2*	1.7*		.3	1.4*		.5	-.9	
	C	1.5	3.4		2.1*	.5		-.3	-1.0	
		Occipital EEG			Occipital EEG			Pulse Rate/Min.		
	E	-2.2*	-1.5*		-1.5*	-1.7*		-.6	.8	1.4
	C	-1.2	-1.2*		-.9*	-1.8*		-2.8	-1.1	1.7

*p < .05

"Difference" columns of Table 2. For example, in Experiment I, tongue EMG of Group E did not noticeably increase from rest to reading before the reading improvement course; after the reading course, however, the increase was .4 μv. yielding a net increase of .4 μv. That increase in amplitude of tongue EMG as a measure of covert oral behavior was significant ($p < .05$). The corresponding change for Control Group #1 was -.4 μv. The increase of .4 μv. for Group E was thus large relative to that for Group C_1 and the difference between these two groups would have been significant beyond the .06 level ($t = 2.03$). Considering only the change from rest to reading for the laboratory session after the reading improvement course, the two control groups did not differ significantly on tongue EMG, or in fact on any of the measures. Similar results were obtained for Experiments II and III, i.e., in Experiment II, Group E increased the amplitude of its tongue EMG from before to after the reading course by .4 μv., while there was a decrease of -.3 μv. in the control group; in Experiment III, the increase for the experimental group was .2 μv. and the decrease for the control group was -.2 μv. However, the changes in tongue EMG were not significant for either group in Experiments II and III, nor were differences between groups significant. It may be that the significant increase in tongue EMG in Experiment I occurred because the subjects were adults and thus emitted relatively small tongue EMG during silent reading prior to the experiment. The children in Experiments II and III, on the other hand, had exaggerated tongue EMG (relative to that for adults) prior to the experiment. Hence, the course could produce a greater effect on the adults (who started from 0.0 μv. amplitude during the pre-test, as can be seen in Table 2) than for the children (who had mean amplitudes of .6 μv. and .3 μv. in the pretests).

It has previously been reported that tongue EMG is probably the most sensitive measure of covert oral behavior (McGuigan & Rodier, 1968), a finding that perhaps explains why lip EMG, and especially throat EMG, were not particularly sensitive to the experimental treatment. In short, basing this conclusion primarily on the tongue EMG measures, there is some evidence that improvement in reading proficiency results in an increase in covert oral behavior. The main support for this conclusion is a consistent tongue EMG increase in three experiments for the reading improvement group, and a consistent tongue EMG decrease for the control groups. Regardless, however, it is clear that the reading improvement effected here did not result in a decrease in amplitude of covert oral behavior.

Conclusion

Previous findings of heightened covert oral behavior during silent reading were confirmed. The increased level of covert oral responding was generally accompanied by increased respiration rate and decreased EEG amplitude, and was independent of one measure of covert non-oral behavior. The reading improvement course was effective and resulted in a decrease in the kind of eye movements that occur when one reaches the end of a line of prose, suggesting that subjects learned to sometimes read more than one line simultaneously. Increasing reading rate seemed to increase amplitude of the most sensitive oral measure (tongue EMG), and the effect was more noticeable for adults; but in any event, improved rate did not result in decreased covert oral activity. Perhaps a greater increase in reading rate than occurred here would make this covert behavioral effect more pronounced, or disconfirm it. The results are thus at least somewhat consonant with the hypothesis that covert oral behavior is beneficial in the performance of language tasks such as silent reading; they also are rather clearly at variance with the position that covert oral behavior is detrimental to reading proficiency.

COVERT BEHAVIOR AS A DIRECT ELECTROMYOGRAPHIC MEASURE OF MEDIATING RESPONSES

Abstract

Electromyographic (EMG) measures (in addition to eye activity, and electroencephalograms, EEG) were taken from the tongue and arms of children under conditions of verbal oral mediation, non-oral (leg and arm) mediation based on the concepts of right and left, and no-mediation. It was found that amplitude of tongue EMG (a measure of covert oral behavior) significantly increased only for the Verbal Mediation Group, and the increase was significantly greater than for the other two (control) groups. The arms were possible loci of mediational behavior for the Non-oral Mediation Group; arm EMG was relatively large under this non-oral mediation condition, the changes being significant for the left arm. Eye movements, possible indicators of right and left mediational activity, were greater under the non-oral mediation condition, too. These psychophysiological measures of covert behavior during mediation are thus consistent with verbal mediational theory that has been based on the study of overt behavior.

COVERT BEHAVIOR AS A DIRECT ELECTROMYOGRAPHIC MEASURE OF MEDIATING RESPONSES

The limited power of single unit S-R laws to explain complex behavior has led to the postulation of an increasing number and variety of hypothetical constructs. Hull's (1952) r_G, Kendler and Kendler's (1969) *mediational response*, Osgood's (1953) *mediating reaction*, Schoenfeld and Cumming's (1963) *perceptual response*, and Underwood's (1965) *implicit associative response* are a few examples. Independent of this development, there has been an exponential growth in psychophysiological research (Ax, 1964). To a large extent, the goals pursued in the development of hypothetical constructs and in the measurement of psychophysiological variables have been similar. To consider the former first, a major purpose of the behaviorists' hypothetical constructs has been to specify events that occur between the external stimulus (*S*) and the overt response (*R*). It is important to emphasize that the overt response is distinguished from the covert response for, in fact, many have postulated the occurrence of covert (implicit) responses (*r*) between *S* and *R* in such paradigms as: S-r-s-R. Similarly, a major purpose of the psychophysiologist has been to directly record various covert processes (electromyograms, electroencephalograms, galvanic skin responses, etc.) that occur as a result of the external stimulus, but prior to the overt response (*R* as opposed to *r*). It is possible that a hypothetical construct, hypothesized to be a covert response (*r*), may be directly measured as an electromyogram that occurs after an external stimulus, but before an overt response -- the covert electromyographic response may be an antecedent or determiner of the following overt response. Consequently, by relating the hypothetical constructs of the theoretician with the directly measured empirical (both central-neural and peripheral-effector) events of the psychophysiologist's laboratory, progress in both areas should be enhanced. It was the purpose of this study to attempt to obtain psychophysiological data relevant to the direct measurement of a hypothetical construct as a mediating response.

A paradigm was used in which mediational activity was anticipated to occur in one particular bodily region, *viz*., the oral speech mechanism. More particularly, we sought evidence of mediation as heightened covert oral behavior (in the form of increased electromyographic activity in the speech region), relative to amplitude of covert oral behavior under two control conditions: (i) where the mediator was not likely to be oral; and (ii) where there was no mediator at all.

Methods and Materials

Subjects. Six boys and six girls, ages 11 to 13 years, were randomly assigned to three groups, with an equal number of each gender in each group. This age level was chosen because it had previously been demonstrated that the ability for mediated transfer is well established by that time (Kendler, in press).

Apparatus. Locations for electromyograms (EMGs) were as follows: Bipolar vacuum-type electrodes were placed on the tongue, separated by about two centimeters; bipolar surface disc-type electrodes (manufactured by Grass Company) were placed on the left and right forearms and calf of the right leg following the placements of Davis (1959). Electrodes were also placed at the external canthus of each eye for eye activity, and bipolar electroencephalograms (EEGs) were recorded from over the motor area of the dominant hemisphere. Signals from each placement were led from the *S* room to the apparatus room for amplification (X 100,000) by two Tektronix 122 Amplifiers and one channel of a Honeywell galvanometer amplifier placed in series, and for recording on a Sanborn seven-channel data tape recorder. The *S* and apparatus rooms were effectively shielded by high permeability steel and a magnetic liner built into the walls, ceilings and floors (for further details of the apparatus, laboratory, and general procedure, see McGuigan and Rodier, 1968). Stimulus material was presented from the apparatus room through a slit in the shielding by means of a shielded 35 mm slide projector controlled by an external timer.

Procedure. The subjects were introduced to the laboratory with assurances that they would not feel anything from the electrodes, the electrodes were attached and the subjects were instructed to relax. The three groups of subjects served under the following conditions: Verbal (Oral) Mediation, Non-oral Mediation, and a No-Mediation Control condition. Briefly, the Verbal Mediation Group learned verbal oral responses that could serve as covert mediators for a consequent overt response; the Non-oral Mediation Group did not make verbal responses but, rather, had a direction response (pushing a button on the right or left) that could serve as a mediator; finally, the control group merely engaged in activities comparable to the other two, but did not have the opportunity to mediate. The paradigm for mediated transfer was adapted from that of Kendler (in press); it and the nonsense symbols used are presented there in detail. There were four critical phases of the paradigm for each group (Table 1). During Phase I four nonsense symbols were exposed five times each while the subjects merely observed them. During Phase II the Verbal Mediation Group was told to orally respond "One" or "Two" to each of the symbols (as indicated), the Non-oral Mediation Control Group was instructed to press a button with their left or right foot to each stimulus presentation, and the No-Mediation Group was told to press a button with their left or right hands. After the initial instructions the subjects practiced to a criterion of five consecutive correct responses to each stimulus, being told "right" or "wrong" after each response. The interstimulus interval for all phases varied about a mean of 10 sec. (± 2 sec.) and the stimuli were presented in a random order. During Phase III all subjects were

TABLE I. Paradigm for Verbal Mediation with Two Control Conditions ["R" indicates the Overt Response made to each Nonsense Symbol (NS)]

	Condition		
Phase Number	Verbal Mediation	Non-oral Mediation (control)	No-Mediation (control)
I	Four Nonsense Symbols visually presented to all groups.		
II	NS #1–R "One"	NS #1–R (left foot)	NS #1–R (left hand)
	NS #2–R "Two"	NS #2–R (right foot)	NS #2–R (right hand)
	NS #3–R "One"	NS #3–R (left foot)	NS #3–R (left hand)
	NS #4–R "Two"	NS #4–R (right foot)	NS #4–R (right hand)
III	NS #1–R (left hand)	NS #1–R (left hand)	NS #1–R (left hand)
	NS #2–R (right hand)	NS #2–R (right hand)	NS #2–R (right hand)
IV	NS #1–R (left hand)	NS #1–R (left hand)	NS #1–R (left hand)
	NS #2–R (right hand)	NS #2–R (right hand)	NS #2–R (right hand)
	NS #3–Covert oral mediation?	NS #3–Covert non-oral mediation?	NS #3–No-mediation
	NS #4–Covert oral mediation?	NS #4–Covert non-oral mediation?	NS #4–No-mediation

instructed to respond to Nonsense Symbol #1 by pressing a button with the left hand and to Nonsense Symbol #2 with the right hand, under the same conditions as for Phase II. In Phase IV (the mediation phase), all four stimuli were randomly presented five times each, but the subject was not told when he was "right" or "wrong." There is ample prior evidence for mediated transfer with this class of paradigm (*cf*. Kendler and Kendler, 1969, and Kendler, in press). In particular, subjects under the verbal mediation condition overtly exhibit mediation during Phase IV by pressing with the left hand to Nonsense Symbol #3 and with the right hand to Nonsense Symbol #4; the subjects in the present experiment were instructed so that they did not force the overt hand responses to Nonsense Symbols #3 and #4, thus preventing any covert arm electromyographic responses during this critical mediational phase that would be merely anticipatory to the typical overt behavior of pressing left and right. In a final phase, a check showed that the subjects had retained the responses learned in Phase II.

Theoretical Predictions. The expectation from verbal mediation theory is that the following chains were extablished during Phases II and III in the Verbal Mediation Group:

$$\text{NS \#1}\_\_\_\_\_\_\,r_{\text{"one"}}\,\_\_\_\_\_\_\,S\,\_\_\_\_\_\_\,R_{\text{Press Left}}$$

$$\text{NS \#2}\_\_\_\_\_\_\,r_{\text{"two"}}\,\_\_\_\_\_\_\,S\,\_\_\_\_\_\_\,R_{\text{Press Right}}$$

Note that the covert oral responses of "one" and "two" had also been established to Nonsense Symbols #3 and #4 as a result of training in Phase II, and that in Phase III $r_{\text{"one"}}$ and $r_{\text{"two"}}$ were antecedents for the overt responses to NS #1 and NS #2 of pressing left and right, respectively. Therefore, when $r_{\text{"one"}}$ and $r_{\text{"two"}}$ are evoked by Nonsense Symbols #3 and #4 in Phase IV, they are the antecedents for the normal pressing responses to these stimuli that have previously been established as the overt evidence of mediated transfer, i.e.,

$$\text{NS \#3}\_\_\_\_\_\; r_{\text{"one"}}\_\_\_\_\_\; S\_\_\_\_\_\; R_{\text{Press Left}}$$

$$\text{NS \#4}\_\_\_\_\_\; r_{\text{"two"}}\_\_\_\_\_\; S\_\_\_\_\_\; R_{\text{Press Right}}$$

Consequently, the expected covert oral responses of "one" and "two" to Nonsense Symbols #3 and #4, respectively, in the mediation phase were hypothesized to be psychophysiologically recordable as heightened speech muscle EMG. Furthermore, these covert oral responses should occur very rapidly after the onset of Nonsense Symbol #3 and Nonsense Symbol #4, and prior to the overt pressing response; hence, the selection below of the first second of stimulus presentation for response quantification. Neither of the two control groups should show heightened covert oral behavior to Nonsense Symbol #3 and Nonsense Symbol #4 since only limb (non-oral) responses were made to these stimuli during training. The Non-oral Mediation Group, though, might be expected to show similar covert activity in the right and left sides of their bodies while mediating; the arms are the more likely locus for recording EMG indications of such mediation, as it has been shown that the arms are rather active during thinking (e.g., Davis, 1939).

Quantification. The signals recorded on tape during Phases I and IV were converted to mean integrated response amplitudes using the method reported by McGuigan and Rodier (1968). The integrating system was activated by a triggering signal that coincided with the onset of the visual stimulus presentations so that the first second of each stimulus presentation was accurately specified for the response quantification. Briefly, this digitizing procedure was to feed the signals into an RMS voltmeter which emitted a dc level signal that could vary between 0 and -1 v. The resulting dc signal then entered a voltage-to-frequency converter which emitted pulses that were proportional (in frequency) to response amplitude. These pulses were counted by an electronic counter for the initial one-second interval, printed out by a digital recorder and converted to voltage at the subject.

Results and Discussion

The mean integrated response amplitude ($\mu\underline{v}$) for each measure was quantified for the first second of each stimulus presentation for Nonsense Symbols #3 and #4. A mean value (pooling the results for the two stimuli) was then computed for each subject for the initial phase (Phase I) and for the mediation phase (Phase IV). Separate means, however, were computed for Nonsense Symbols #3 and #4 for the arm EMGs so that we could study "right" versus "left" activity during mediation. Group means were then computed (Table 2). The Verbal Mediation Group had a mean tongue response of 8.3 $\mu\underline{v}$ during this initial phase, which increased to 13.9 $\mu\underline{v}$ during the mediation phase; this mean increase of 5.6 $\mu\underline{v}$ is significantly different from zero ($\underline{t}$ = 6.83). The mean increases of the tongue response for the two control groups of 1.3 $\mu\underline{v}$ and .9 $\mu\underline{v}$ were not significantly different from zero. Furthermore, the mean increase for the Verbal Mediation Group was significantly greater than for the Non-oral Mediation Group ($\underline{t}$ = 3.46), and for the No-Mediation Group ($\underline{t}$ = 3.51). The two control groups did not differ significantly on the tongue measure. There were no other significant differences between the Verbal Mediation Group and the two control groups. The fact that no response measure other than tongue EMG changed significantly from the initial to the test phase for the Verbal Mediation Group indicates that the heightened covert oral behavior for this group was not merely an aspect of a state of general arousal -- rather, the suggestion is that the response change was localized in the oral region. Furthermore, the effect occurred only for the oral mediation conditions; i.e., Nonsense Symbols #3 and #4 evoked relatively heightened covert oral behavior only in the Verbal Mediation Group, not in the two control groups.

Table 2. Mean Response Amplitudes to Test Stimuli (μv) for Initial Level (Phase I) and Mediation Phase

	Condition								
	Verbal Mediation			Non-oral Mediation (control)			No-Mediation (control)		
Measure	Initial	Test	Difference	Initial	Test	Difference	Initial	Test	Difference
Tongue	8.3	13.9	+5.6*	9.8	11.1	+1.3	8.7	9.6	+0.9
EEG	14.2	14.0	−0.2	13.6	14.8	+1.2	13.7	13.1	−0.6
Eye	7.1	7.4	+0.3	6.5	7.6	+1.1*	6.3	6.2	−0.1
Right Leg	2.9	3.1	+0.2	2.4	2.2	−0.2	3.4	3.2	−0.2
Left Arm									
NS #3	6.8	7.2	+0.4	2.6	6.0	+3.3*	9.4	5.9	−3.5
NS #4	6.8	8.0	+1.2	2.1	7.9	+5.8*	8.4	5.5	−2.9
Right Arm									
NS #3	13.0	12.1	−0.9	2.1	5.2	+3.1	6.3	7.8	+1.5
NS #4	11.5	13.8	+2.3	2.0	5.2	+3.2	6.6	6.5	−0.1

* $P < .05$

These findings are in accord with the theoretical expectations specified above, viz., that the heightened covert oral behavior recorded for the Verbal Mediation Group may actually have been a direct measure of mediating responses.

While the effort here was only to test for relatively heightened covert oral behavior from the initial to the mediation phase, future research could be more definitively designed. For one, it might be possible to distinguish between different oral mediators, e.g., to identify different patterns of covert oral behavior that may correspond to "subvocal" responses of "One" and "Two."

The purpose of the Non-oral Mediation Group was to provide control data on the locus of the oral mediating response in subjects who mediate but presumably with non-oral mechanisms. As stated earlier, it is conceivable that evidence for the mediating response for this group could be found in the arms when Nonsense Symbols #3 and #4 were presented. Table 2 indicates that the arm responses were in fact relatively high for this group -- left arm EMG significantly increased to both Nonsense Symbol #3 and Nonsense Symbol #4, and the increase was significantly greater for the Non-oral Mediation Group than for the No-Mediation Group (t = 2.76); no other differences between groups were significant. Neither arm EMG significantly increased for either of the other groups. The relatively large activity in the arms is, thus, suggestive of mediational behavior for this group. However, the complex interaction of covert behavior in two arms (perhaps through bilateral transfer) makes it difficult to differentially isolate covert mediators of "Right" and "Left" in these limb regions. The significant change in eye activity from the initial mediation phase for the Non-oral Mediation Control Group, though, is suggestive in this regard: Perhaps slight visual glances to the right and left are covert responses indicative of right and left mediational activity under this condition

The failure of any measure to change significantly for the No-Mediation Group suggests that the critical oral and arm changes for the other groups were more than merely low order conditional responses. That is, if the oral and arm changes from Phases I to IV for the Verbal Mediation and the Non-oral Mediation groups, respectively, were due to conditioning, the same type of effect should have occurred for the No-Mediation Control Group; but that obviously is not the case. In conclusion, then, these psychophysiological measures of covert behavior during mediation are consistent with verbal mediation theory derived from the study of overt behavior.

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THE GILBERT AND SULLIVAN EFFECT: ENHANCEMENT OF SPEECH PERCEPTION BY SIMULTANEOUS READING

It has been amply demonstrated that perception in one modality may be facilitated by increasing stimulation in another (see, for example, Hartman, 1933, Kekcheev, Kravkov and Shvarts, 1954; Zwosta and Zenhausern, 1969). However, these are all cases of generalized, non-informational facilitation. The only studies we have been able to locate in which specific facilitation across auditory and visual modalities is investigated are reported by W. M. Smith (1965 a, b). Smith found that near-synchronous presentation of auditory verbal stimuli facilitates tachistoscopic recognition of the "same" verbal stimuli in the visual mode. Only the thresholds for matched, not mis-matched, three-syllable words showed this effect. According to Smith (1965 b), the fact that the effect occurs when another's voice (the experimenter's) is heard synchronously with the visual display, as well as when the subject himself speaks the words (repeating the experimenter), eliminates feedback from the speech musculature as an explanation. However, the possibility that the subjects were sub-vocalizing while listening to the experimenter is not eliminated. Therefore, Smith's results offer another instance of the G-S effect (albeit in reverse, hearing upon reading), but they do not help to differentiate between covert oral and representational sources of facilitation.

There seems to be no question but that covert oral responses do increase measurably during the silent performance of linguistic tasks. Restricting ourselves to those EMG studies which meet three methodological criteria (McGuigan, 1970) -- that the covert oral EMG increase significantly during silent linguistic performance, that it do so independently of simultaneous measures at other loci, and that it not occur under non-linguistic performance conditions -- we may note Jacobson's (1932) positive evidence for tasks like "imagine counting" and "recall a poem," McGuigan and Rodier's (1968) positive evidence for enhanced covert oral behavior during silent reading (due to simultaneous listening to prose), and McGuigan's (1970) positive evidence during writing words vs. non-linguistic tasks. Furthermore, it has been concluded by many investigators (e.g., Schilling, 1929, Edfeldt, 1960, McGuigan, 1970, Sokolov, 1969) that covert oral behavior has beneficial effects upon the performance of linguistic tasks. McGuigan (1970) hypothesized the covert oral response to be a critical event in extremely rapid and complex feedback loops among the speech regions of the brain, the vocal musculature, the inner ears, the eyes and so on -- all involved interactively, for example, in reading aloud and presumably in reading silently as well. More particularly, he suggests that covert oral responses generate verbal codes, these codes being carried in afferent neural impulses, performing an integrative function among the linguistic regions of the body, and serving to amplify code distinctions in these other regions.

In short, the two theoretical issues are:

(1) Is such demonstrable covert oral activity _necessary_ for linguistic processing? This was the original question posed by the Jacobson (1932), Max (1935) and in related EMG studies. It is conceivable that sub-vocal activity is nothing more than excitatory overflow along those pathways ordinarily involved in overt execution -- and like the noise of an engine, not essential to its functioning. A compromise view would be that while peripheral involvement is necessary for the _development_ of language, including both phonological and semantic codes, it is no longer necessary for adult linguistic performance (cf., Osgood, 1953, pp. 653-655).

(2) Is such demonstrable covert oral activity _sufficient_ for linguistic processing? If proprioceptive feedback from the vocal musculature were to provide anything more than a generalized tonic effect upon language

perception or meaning, it would have to display precisely particularized relationships to the auditory linguistic stimuli. This is certainly true for overt speech, but it must be shown to hold as well for covert speech.

Although it is not required that covert speech be a miniature of overt speech -- resemble it in every way except amplitude -- there is some evidence for a reasonably close resemblance. For example, heightened covert oral EMG during silent reading and during auditory hallucination may be accompanied by slight "whispering" that can be understood as English words by the experimenter (Gould, 1949, McGuigan et al, 1964, McGuigan, 1966). Locke and Fehr (1970) had adult subjects perform a serial learning task using visually presented disyllabic words characterized by the presence or absence of letters representing labial phonemes; mean peak amplitudes of lip EMG were significantly greater for labial than for nonlabial words during both presentation and rehearsal. To the extent that this issue can be resolved affirmatively, then an affirmative answer to issue (1) becomes much more likely.

To summarize, McGuigan's "peripheral" theory would explain the Gilbert-Sullivan effect in terms of "enhancement" of the auditory signals by feedback from the vocal musculature, the feedback being produced by covert reading of the clear visual signals. Osgood's "central" theory would explain the G-S effect in terms of representational-level feedback from the meanings (s_M) of the words which are normally near-synchronous with clear hearing, but here are produced by "synonymous" and clear visual signs.

Method

Eight volunteer undergraduates at Hollins College served as subjects in Experiment I. They were introduced into the laboratory (see McGuigan & Rodier, 1968 for details on apparatus and general procedures) and the usual assurance that they would be harmed in no way were given by the experimenter. Surface electrodes were placed on the chin, lip, tongue and right calf for recording electromyograms. The subjects were told that they would listen to several pieces of choral music and would simultaneously be viewing several slides containing the printed passages, that sometimes the printed words would help them understand the words being sung and sometimes not, but that they were to pay attention to the music, pressing a button during periods when they felt they could clearly hear and understand the words _being sung_ and releasing the button when they could not clearly hear and understand. This is our measure of _subjective understanding_ of the auditory materials.

A panel of three independent judges had previously listened to various male chorus sections of several Gilbert and Sullivan operettas, being instructed simply to write "yes" or "no" next to the selection numbers to indicate when they "could clearly hear and understand" a majority of the words and when they could not. Passages judged _unanimously_ "yes" were selected as highly intelligible (HiI) and those judged unanimously "no" as of low intelligibility (LoI) for the experiment.

Five musical selections of 40 sec. duration were presented to each subject: two were HiI, two were LoI, and one selection was purely instrumental music. Each subject served as her own control, with the order of the four choral selections being counterbalanced across subjects. The musical selection was last in all cases. The order of slides during each selection was: 10 sec. blank slide, 10 sec. matching _or_ non-matching visual slide, 10 sec. blank slide, and 10 sec. matching _or_ non-matching slide; the order of matching and non-matching slides in slots two and four was randomized. After each 40 sec. selection the subject was given a recognition test containing 10-12 phrases from the actual choral passage, three or four items from the non-matching (visually presented) passage, and 10 extraneous phrases from other operettas. For all except the purely instrumental selection (where they were to check items *seen*), subjects were instructed to "check those items which you recognize as having been *sung*." These recognition scores are our measure of *objective understanding*. There were periods of relaxation (monitored by the EMG levels) prior to the first selection and after each following selection.

Results

Turning now to the results, we may note first that the subjects *did* reliably report the subjective G-S effect: they signalled understanding of the LoI choral material during 60% of its presentation time when the accompanying slides matched the sung words, as against 11% of the time when non-matching slides accompanied the music (t = 4.11, p = < .05; α = .05 throughout) and as against 17% of the time for the LoI/Blank-slide condition (p = < .05). That the subjects were signalling understanding of the words actually being *sung*, as instructed, is shown by the fact that they not only signalled understanding for HiI 86% of the time for matching slides, but also 84% of the time for non-matching slides.

Recognition scores were computed as the percentage of items from the actual choral passages that were correctly identified. Over-all veracity of the *subjective* reports of understanding is indicated by the fact that *objective* recognition scores were higher for choral passages signalled "understood" (48% correct) than for those signalled "not understood" (22% correct); this difference is also significant at the .05 level.

A more stringent test of the G-S effect is provided by the data shown in Table 1. Recognition scores for the LoI/Matching-Slide Understood condition (54%) were significantly higher (p = < .05) than for LoI/Blank-slide/Not-understood condition (10%), the subjects thus reporting that relatively unintelligible passages become perceptually clear in the *auditory* modality

TABLE 1

Recognition Scores for G-S Choral Music (Percentage of Items Correct) as Functions of Visual Conditions and Subject Reports

REPORT OF SUBJECT	MATCHING SLIDE	NON-MATCHING SLIDE	BLANK SLIDE
Understood			
HiI Selections	69% (n=8)	46% (n=8)	26% (n=8)
LoI Selections	54% (n=8)	50% (n=2)	20% (n=6)
Not Understood			
HiI Selections	67% (n=3)	00% (n=2)	47% (n=8)
LoI Selections	44% (n=6)	10% (n=8)	10% (n=8)

when the same words are being seen in the visual modality. Testifying to the validity of the judges' classifications of selections as to their intelligibility, we note that for both Matching-slide and Blank-slide conditions (whether Understood or Not) HiI selections get higher recognition scores than LoI selections; this does not hold for the Non-matching-slide condition, but two of the cells have N's of only 2.

The strange recognition scores for the Blank-slide condition -- only 26% for HiI/Understood but 47% for HiI/Not-understood -- are probably due to (a) the fact that one Blank-slide condition was always first in order for each selection (and hence could not benefit from any perseveration effects) and (b) the fact that the other Blank-slide condition followed either a Matching-slide (conducive to subjective understanding) or a Non-matching slide (not conducive)condition. To check this out, as shown in Table 2, we compared subjective understanding and objective recognition scores for the 1st and 2nd blank-slide periods separately, the latter being differentiated in terms of whether the immediately preceding slide had matched or had not matched the auditory material. First, note that for the 1st Blank-slide condition, without benefit of any warm-up, both signalled understanding and recognition scores are typically low, relative to values for the 2nd blank-slide period. Second, note that, for the 2nd Blank-slide condition, signalled understanding of the LoI choral music (64%) was significantly higher than recognition scores (12%) when a matching-slide had just preceded; when a non-matching slide had preceded, however, there was practically no subjective understanding (2%) and absolutely no recognition. Apparently, when subjects have really been understanding the music (with the aid of a matching slide) and a blank slide comes on, they persevere in an illusion of understanding even though they do not (without the aid of a matching slide), as the recognition scores indicate.

TABLE 2

Signalled Understanding and Recognition Scores for Blank-slide Periods, the Second Following Either Matching or Non-matching Visual Materials

	1st BLANK-SLIDE PERIOD	2nd BLANK-SLIDE PERIOD	
		Following Matched /	Following Non-matched Visual Material
% TIME SIGNALLED UNDERSTOOD			
HiI Selections	55%	64%	54%
LoI Selections	2%	64%	2%
RECOGNITION SCORES			
HiI Selections	28%	44%	50%
LoI Selections	12%	12%	00%

There is, of course, an alternative explanation that must be countered before we can accept the validity of the G-S phenomenon. This is the possibility that our subjects were not really following instructions to attend to the sung words but were attending to what really was clear, viz., the visual words -- they may have reported subjective understanding in a self-deceiving fashion when the two inputs happened to match. There are several lines of evidence against this explanation: (1) As already noted, subjects signalled understanding of the HiI/Non-matching-slide choruses nearly as often (84%) as for the HiI/Matched-slide choruses (86%), whereas they signalled much less understanding for the LoI conditions -- if the subjects were reading instead of listening, these values for HiI and LoI conditions would be about equal. (2) Recognition scores on items from the visually presented materials for the purely instrumental music conditions were much higher (74%) than for the Non-matching-slide/LoI/Non-understood conditions (12%); if the subjects had been attending to the non-matching slide materials in the latter case, why were their recognition scores for these materials not higher? (3) If the subjects were not paying attention to the sung words, why was the recognition for the choral (auditory) material as high as it was (46% correct) under the Non-matching-slide condition? (4) As is clearly evident from Table 3, the over-all recognition scores for the visually presented materials (3 or 4 items on the recognition tests for choral selections) are extremely low: for both HiI and LoI choral selections, not a single subject got a single item correct when the Non-matching-slide condition was first in order (following the initial blank slide); when the Non-matching-slide condition came second, there was only an average of 8% (3/24 possible) correct recognitions of visually presented material for HiI selections and only 12% (4/32 possible) correct for LoI selections. If subjects were simply reading the slides, then they certainly didn't retain much of what they had read.

TABLE 3

Recognition Scores for Materials Presented Visually on Non-matching Slides During HiI and LoI Choral Music

SUBJECT	HiI SELECTIONS		LoI SELECTIONS	
	When		When	
	1st	2nd	1st	2nd
	in Presentation		in Presentation	
#1	00%	00%	00%	00%
#2	00%	66% (2/3 items)	00%	00%
#3	00%	00%	00%	00%
#4	00%	00%	00%	75% (3/4 items)
#5	00%	00%	00%	00%
#6	00%	33% (1/3 items)	00%	00%
#7	00%	00%	00%	25% (1/4 items)
#8	00%	00%	00%	00%
Means	00%	08% (3/24 items)	00%	12% (4/32 items)

The final question for this experiment concerns the EMG measurements made from tongue, chin, lip and leg locations. One hypothesis, it will be recalled, is that heightened covert oral behavior should occur during perceptual clarification -- the G-S Effect. The required comparison would be for oral behavior during the G-S Effect, relative to one in which there was lack of understanding, but with controls for general activation due to slide changing, etc. Consequently, means for each subject were computed for two conditions: (1) that in which Lo-I singing was accompanied by a matching slide and understanding was reported; and (2) that in which Lo-I singing was accompanied by a blank slide and no understanding was reported. These values were then used to compute a ratio that corrects for individual differences, based on the work of Lykken, Rose, Luther and Maley (1966). The larger the ratio, the greater the response amplitude. The results are presented in Table 4. There it may be noted that amplitude of tongue EMG (typically the most sensitive measure of covert oral behavior) was significantly higher under the condition in which the integration effect occurred (viz., .63 vs. .44, $\underline{p} > .05$). Since the non-oral measure (leg EMG) was relatively low in amplitude, and since the difference here between the two experimental conditions did not approach significance, it seems likely that the behavioral change was localized in the speech region. We, therefore, have some reason to believe that covert oral activity (in the tongue, where one would most expect it) does occur with higher amplitudes when the G-S effect is present than when it is absent.

The result of this experiment in our planned series of four thus give us reasonable confidence that the Gilbert-and-Sullivan effect is a valid phenomenon -- that presentation of synonymous material in one communication modality can clarify perception in another modality. But at this point both peripheral (covert oral) and central (meaningful) feedback mechanisms remain as possible explanations.

TABLE 4

Mean Ratios of Covert Response Amplitudes for LoI Selections as Functions of Slide Conditions and Understanding of Choral Materials

MEASURES	MATCHING-SLIDE	BLANK-SLIDE	*t*
	UNDERSTOOD	NOT UNDERSTOOD	
Tongue EMG	.63	.44	2.48*
Chin EMG	.50	.46	0.49
Lip EMG	.40	.31	1.14
Leg EMG	.26	.18	0.90

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EXTERNAL AUDITORY FEEDBACK FROM COVERT ORAL BEHAVIOR DURING SILENT READING

Abstract

Subjects were selected for high levels of covert oral behavior during silent reading. High speech-muscle amplitude during silent reading produced a slightly noxious tone, and a reduction in amplitude removed the tone. Feedback reduced amplitude of the controlling and associated speech muscles, but withdrawal of feedback returned the amplitude to about baseline level, indicating that the reduction was not permanent. More effective controlling techniques are required to determine stringently the function of the covert oral response with this approach.

EXTERNAL AUDITORY FEEDBACK FROM COVERT ORAL BEHAVIOR DURING SILENT READING

There are two opposing views of the function of covert oral behavior during the performance of such linguistic tasks as silent reading: the traditional one that "subvocalization" is detrimental (e.g., Wood, 1966) and the alternative (recently revived) that the covert oral response facilitates the reading process (e.g., Edfeldt, 1960; McGuigan & Rodier, 1968; McGuigan, 1970). One approach to help decide between these positions would be to decrease experimentally amplitude of covert oral behavior during silent reading and to observe the consequences on reading proficiency. First, however, we need to develop effective control over the covert oral response. External feedback from the speech musculature might serve for this purpose. To date, however, only sparse and inconclusive data have been reported on efforts to manipulate this response class (e.g., Hardyck, Petrinovich, & Ellsworth, 1966; McGuigan, 1967; Hardyck & Petrinovich, 1969).

Method

Initial screening produced six subjects with high levels of covert oral behavior during silent reading. Each subject was introduced to the laboratory, and sensors were attached to various oral and nonoral regions of the body (see below). Each day the subject relaxed and then silently read a different passage standardized for his educational level. After a series of daily adaptation sessions of reading without feedback (three to seven, depending on the subject), auditory feedback signals from the speech musculature were introduced. During the feedback sessions (from 2 to 20, depending on the subject), electromyographic (EMG) signals from the chin or lips automatically produced a slightly noxious tone (a potential punisher) when the subject's response amplitude exceeded a specified level. A reduction of the response amplitude below that level terminated the tone (a potential negative reinforcer). The response amplitude that would produce feedback was specified for each subject such that the tone would have been produced about 50% of the time during the final no-feedback adaptation session. After the feedback sessions, the subjects read for a series of sessions (from 2 to 18) with feedback removed. The criterion for commencing feedback was that the amplitude of the response that was to produce feedback had become reasonably stabilized over sessions. EMGs were integrated and digitized for 10-sec intervals during rest and during reading, and means for each were computed for each subject (cf. McGuigan, 1967, and McGuigan & Rodier, 1968, for quantification details and for other information concerning the laboratory and procedures).

Results

Each mean response amplitude during each prereading rest session was subtracted from the corresponding mean value during silent reading for that day. The psychophysiological results for Subject 1 (a female college student) are plotted as a function of session in the lower part of Fig. 1. No external feedback while reading was given during the first six sessions. Feedback from the chin was started during Session 7, but the subject was not told why the tone was initiated or terminated. The general increase in chin and tongue amplitude through Session 27 suggests that, without awareness of the function of the tone, the subject did not learn to reduce her covert oral behavior. At the start of Session 28, the subject was told (to her amazement) that she controlled the tone, but she was not told how; a gradual decrease in amplitude of chin EMG then followed (Sessions 28-41). For Sessions 7-33, the tone came on when chin amplitude exceeded 20 microV (root-mean-square). For later sessions, the criterion was lowered to 16 and 9 microV, as specified in Figure 1. Through this shaping procedure and by being aware that the tone served a feedback function, the subject substantially lowered the level of her chin response. The accompanying decrease in tongue EMG suggests that the effect was generalized throughout the oral region.

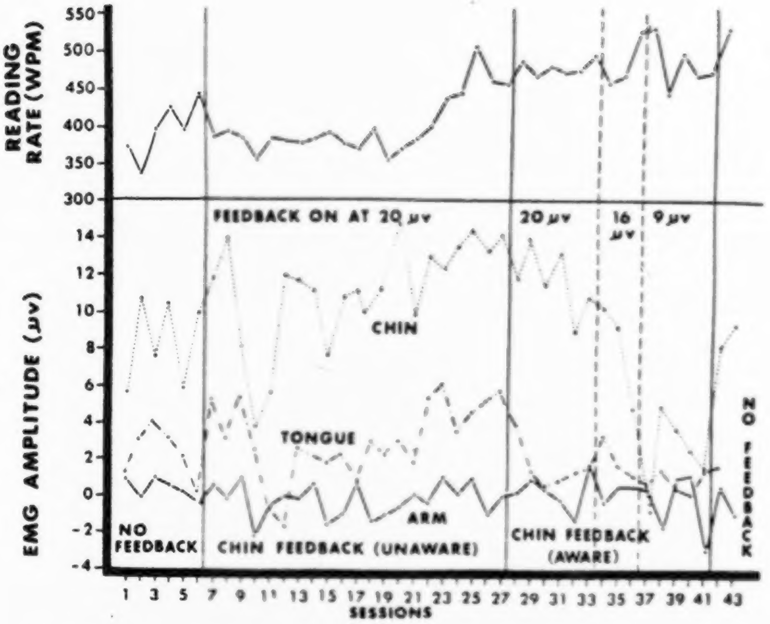

Fig. 1. EMG amplitudes for each session (lower). Feedback started when chin amplitude exceeded 20 microV during Sessions 7-33; thresholds for later sessions were lowered to 16 and 9 microV. Corresponding laboratory reading rates in words per minute (WPM) appear at the top.

Nonpreferred arm EMG was stable around zero throughout, indicating that the subject's originally heightened covert oral behavior during reading was not merely an aspect of general bodily activation; rather, the EMG increase was probably localized in the speech region. Lack of change in arm EMG as a function of feedback condition also suggests that feedback did not have a general disturbing effect and that consequent behavioral changes were localized in the oral region. Finally, when feedback was eliminated (Sessions 42 and 43), chin EMG dramatically increased to approximately the baseline level of Sessions 1-6, indicating that the continuous presence of feedback was responsible for the changes -- there was apparently no permanent change in level of covert oral behavior. There is a hint of a positive relationship between amplitude of speech muscle EMG and laboratory reading rate (top of Figure 1), but in any event, the relationship is clearly not inverse (usable tongue and rate measures were missing from Session 43).

The five additional subjects (two male and three female varying in ages between 7 and 19 years) were studied as was Subject 1, except that after the initial no-feedback adaptation sessions, they were told that the tone was indicative of excessive lip or chin movements and that their task was to prevent the tone's onset. Results (illustrative of the more extended curves) are summarized in Figures 2 and 3. The values plotted are for the last no-feedback session (when the subject was well adapted to the laboratory), for the last feedback session (when feedback had become effective in removing the tone), and for the last session in which feedback was withdrawn. (The value for the last feedback session used for Subject 1 was under the "unaware" condition.) Figure 2 shows that feedback was always effective in decreasing the amplitude of the covert oral behavior (whether from chin or lips) during silent reading and that its withdrawal returned the behavior to approximately baseline level -- the reduced amplitude of covert oral behavior during silent

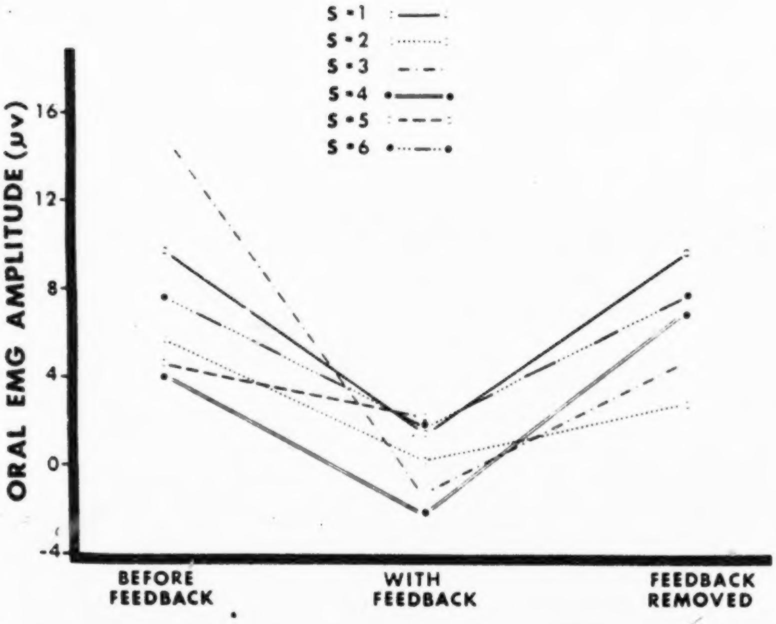

Fig. 2. Effect of feedback presentation and subsequent withdrawal on the triggering covert oral behavior during silent reading. Feedback was from the chin for Ss 1, 3, 4, and 5 and from the lips for Ss 2 and 6.

reading is not permanent, and when it did occur, it evidently was not merely due to instructions to reduce response amplitude. These results are thus at variance with the statements of Hardyck et al (1966) that reduction of speech muscle activity to resting levels is immediate (accomplished by most subjects within 5 min) and long lasting.

The effect of feedback on other covert oral measures was essentially the same as for the one that triggered the feedback: feedback from the lips or chin also depressed associated muscle activity in the lips, chin, and tongue, and the accompanying oral measure typically increased once feedback was removed. The most extreme example was Subject 6, whose lips triggered feedback. The mean increase in chin amplitude from rest to silent reading for Subject 6 was 24.7 microV before feedback; with feedback, the difference between resting and reading was -3.0 microV, while when feedback was removed, the difference in mean chin amplitude increased to 8.1 microV.

Figure 3 shows that heightened covert oral behavior during silent reading is generally independent of nonoral measures and that the administration of feedback and its subsequent withdrawal have little systematic effect on these nonoral measures.

The introduction and subsequent withdrawal of feedback was about equally often accompanied by increased and decreased reading rates, measured as number of words per minute; this measure is probably too insensitive to reflect consequences of the reduced oral response amplitude. Mean comprehension scores during the prefeedback, feedback, and postfeedback sessions were, respectively, 69%, 66%, and 72%, showing that the subjects were comprehending about as well during and after feedback as they were before.

In conclusion, it apears that the presentation of a slightly noxious stimulus contingent on a high level of covert speech muscle activity during silent reading, and the cessation of that stimulus contingent on a decrease

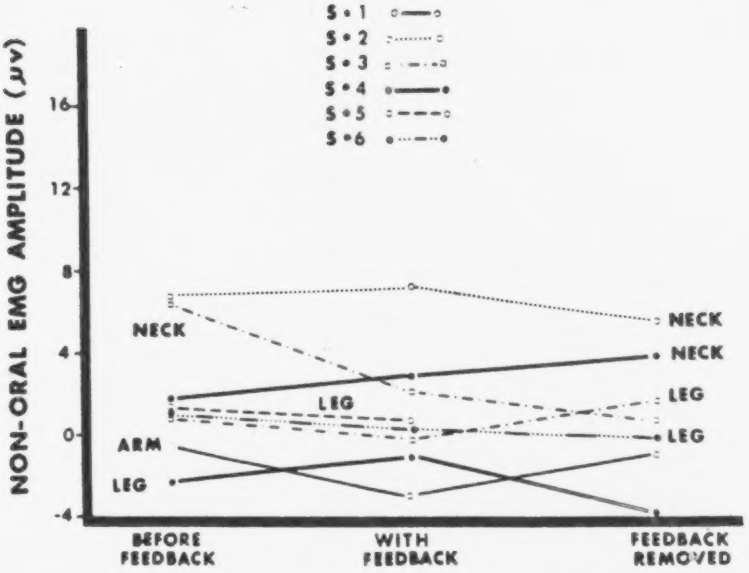

Fig. 3. Amplitude of nonoral response measures during feedback and subsequent nonfeedback reading sessions.

in covert oral behavior, is effective in reducing amplitude of both the controlling and associated speech muscles. But, as indicated by subsequent feedback removal, the reduced amplitude is not permanent. The heightened level of covert behavior during silent reading appeared to be localized in the speech region, and nonoral regions sampled were not systematically affected by feedback condition. Covert oral behavior can thus be only temporarily controlled through feedback techniques as used here. A more prolonged reduction in amplitude would be required before we could apply a "response-reduction" strategy to stringently test alternative hypotheses of the function of covert oral behavior during the performance of such linguistic tasks as silent reading.

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EVOKED POTENTIALS TO AUDITORY STIMULI

Compound evoked potentials (CEPs) recorded from the scalp over the cortex have been demonstrated to occur to stimuli in several sense modalities, in addition to the auditory, which is the subject of this study. Most of the research has been done in the visual modality, apparently for the technical reason of ease of control of the independent variables. Some visual stimulus parameters that have been shown to affect CEPs are shape and size (John, Herrington, & Sutton, 1967), intensity (Ropell, Wittner, & Warick, 1969), frequency of presentation (Gjerdingen & Tomsic, 1970), and movement (Barlow, 1964). CEPs to visual stimuli have also been shown to be related to mental age of adolescent subjects (Rhodes, Dustman, & Beck, 1969). However, as with the relationship between baseline electroencephalogram (EEG) activity (cf., Vogel & Broverman, 1964) this relationship may not obtain or may be substantially attenuated in adults.

CEPs have also been shown to occur to intermittent presentations of olfactory stimuli (Allison & Goff, 1967), somatosensory stimuli in adults (Gjerdingen & Tomsic, 1970) and infants (Hrbeck, Hrbkova, & Lenard, 1969) and to shock (Gjerdingen & Tomsic, 1970; Satterfield, 1965).

More to the subject of this study is research which shows that attention of the subject and informational value of the stimuli affect CEPs. Haider, Spong, and Lindsley (1964) found that CEP amplitude was greater to correctly identified stimuli than to incorrectly identified stimuli. They suggested that CEP amplitude was reflecting vigilance, although this particular interpretation must be regarded as tentative since both CEP amplitude and percentage of correctly identified stimuli declined with time (1.5 hours). Davis (1964) found that higher "meaningfulness" of acoustic stimuli produced higher amplitude CEPs. In his experiment, a meaningful stimulus was one which required a decision. Chapman (1964) recorded evoked potentials to task relevant and irrelevant stimuli while subjects did mental arithmetic.

He found that CEPs to relevant stimuli were larger than those to irrelevant ones. Other investigators (Donchin & Cohen, 1967, for example) have shown that the CEP is affected by instructions to attend to specific parts of the stimulus configuration.

It seems reasonable to generalize from all this that cortical CEPs are related to meaningfulness of stimuli, at least in the sense of being relevant to the subject's task (cf. Uttal, 1964) and to attention level of the subjects. Both of these general observations may reflect the subject's overall degree of involvement with the stimulus.

Finally, one study has suggested a negative relationship between cortical evoked potential amplitude and electromyogram (EMG) amplitude from the frontalis muscle (Bartoshuk, 1956). This result must be regarded as tentative, however, because it was obtained with a continuously integrated recording technique, which of course sacrifices all the topographical characteristics of the responses and because the frontalis recording site might be contaminated by potentials originating in the brain.

The research reported here was an attempt to extend such CEP findings in the area of verbal auditory stimuli. Specifically, patterns of responses to words are compared with those to white noise. Further, two levels of image evoking power of words were used as stimuli. Two extremely high imagery and two extremely low imagery words were selected from the list standardized by Paivio, Yuille, and Madigan (1968). Most previous research has sought only to reduce other bodily activity during recording to reduce contamination of cortical potentials. In this experiment, other covert processes were measured in an attempt to elucidate possible relationships between cortical potentials and peripheral stimuli.

Method

Subjects. Five subjects were used in this study, one 14-year-old boy and four college age girls. Of these, only the boy could be called "naive" in the strictest sense. The girls represented a range of knowledge of physiology, electronics and experimental procedure. None were acquainted with the hypotheses of the experiment, or even offered close guesses after their participation.

Apparatus. The subjects were seated in a comfortable easy chair in a sound dampened room wich was well shielded from extraneous electronic signals. Signals were picked up with silver-silver chloride electrodes and conducted through a wall to a shielded control room where they were amplified and recorded on a Sanborn seven channel data tape recorder. Each channel was wired with an oscilloscope in parallel with the tape recorder to allow monitoring while recording. See Table 1 for further technical information.

Stimuli were presented via a small portable dc tape recorder. Signals were averaged using a Digital Equipment Corporation PDP 8/1 computer and AX08 analog to digital converter. This system permitted triggering on the auditory stimulus and averaging signals prior to the trigger (a negative delay).

Procedure. Four words, two extremely high and two extremely low in image evoking power, and a period of white noise the same volume as the words were the stimuli. The words were all in the Thorndike-Lorge (1944) AA category of frequency of general usage, meaning that they each occurred at least 100 times per 1,000,000 words. This list was presented 32 times in an independent random order each time, within the limitation that the same stimulus was never presented consecutively. The intertrial interval was randomly varied in one second steps from 3 to 7 seconds.

Table 1

Technical Information

	1st amplifier			2nd amplifier
Recording site	Amplifier type	Gain	Frequency range	
Eye	Tektronix 122	100	.2 - 1000 Hz	same
Lip	Tektronix 122	100	8 - 1000 Hz	same
Neck	Tektronix 122	100	8 - 1000 Hz	same
Tongue	Tektronix 122	100	8 - 1000 Hz	same
Nonpreferred arm	Tektronix 122	100	8 - 1000 Hz	same
EEG parietal	Tektronix 410	5000	.1 - 100 Hz	none
EEG occipital	Tektronix 410	5000	.1 - 100 Hz	none

Table 2

Electrode Locations

Recording site	Locations of Electrodes
Eye	One/half inch outside each outer canthus
Lip	One/half inch above left end of mouth, and 1/2 inch below right end of mouth
Neck	One and one/half inches below base of skull and 1 inch on either side of spinal column
Tongue	One inch apart on a lateral line 1 inch from tip of tongue
Nonpreferred arm	One/third and 2/3 of distance on a line from humerous to thumb side of wrist
Parietal (EEG)	One/third and 2/3 of distance on a line from top center of cranium to ear
Occipital (EEG)	One/third and 2/3 of distance on a line from top center of cranium to inion

Note.—The Ss were always wired so that negative polarity of the superior electrodes, or if they were equal in this dimension, the rightmost electrodes corresponded to up on the computer output.

Seven sites were recorded with bipolar pickup technique. See Table 2 for the placements of the electrodes and the names of the sites.

The experimenter and one of two assistants prepared the subject and attached electrodes while the experimenter assured the subject that there was no pain and very little discomfort involved in the experiment. If the subject asked what the experiment was about, he was asked to tolerate ignorance until the end of the session, when the experimenter would tell him all about it. The subject was also told exactly what would happen in the experiment; that all the experimenter wanted him to do was sit and listen to a series of words and white noise. After all experimenters left the room, he was given tape recorded relaxation instructions to reduce overt movement and general tension. Then, following a minute of silence, the series of stimuli was played without interruption.

Quantification of data. Note that there is a variety of topographies that responses could assume which could relate to our stimulus parameters. The most obvious possibilities are a regular change or a series of changes in the amplitude of the potential following stimuli. Such changes or series of changes are called evoked potentials, and examples of them abound in the literature of physiological psychology. Another possibility is a reduction in amplitude of the potential. Although such an observation would be important theoretically, and as easy to measure as any result in this area of research, we know of no previous examples of it, or event attempts to identify it.

Standard deviations of the potentials (=1 and -1) were plotted parallel to the average line on the computer plot-outs. An increase or a decrease in the standard deviation indicates an increase or decrease in the amplitude of the potentials at that point in time related to the T. If there is no associated change in the average trace, it means that the polarity of the change is not constant over trials. A decrease in standard deviation from baseline could be caused by a stimulus blocking unrelated events taking place in the area measured. It could also substitute a related event, which should then show in the average trace, but it need not in order for this explanation to apply. Also the related event might not show if it produced extremely low amplitude evoked potentials. The largest motonic peak to peak fluctuation within each mean response period and within each baseline period was measured for each condition. The response period here is the .4 sec. following the onset of the stimulus (as measured from the point of triggering by the computer). The baseline period was a .4 sec. period prior to each stimulus onset. A response is defined when the absolute amplitude was greater during the stimulus period than during the baseline period.

Where table entries are blank, this is due to electrode failure during the experimental session.

Results and Discussion

The mean maximum amplitude values extracted from the averaged curves (e.g., Figs. 1 & 2) for each subject are presented in Table 3. We can see, for instance, that for the eye measure, subject Evelyn had a maximum peak-to-peak change to all words during the response period of -2 microvolts, that the maximum change during the baseline period was +1 microvolt, the absolute difference being 1 microvolt. These mean differences are summarized in Table 4.

The most salient characteristic of these results is that reactions are most apparent to both words and noise in the two regions of the brain. There is, furthermore, an indication that the reactions were larger to noise than to the words. The EMG responses were few, but some interesting EMG changes did occur, including with the standard deviation measures (e.g., Fig. 3);

Fig. 1. Averaged parietal EEG to 32 presentations of the word "girl" (subject William). Mean curve is in the middle. Top and lower curves are ±1 standard deviation from the mean.

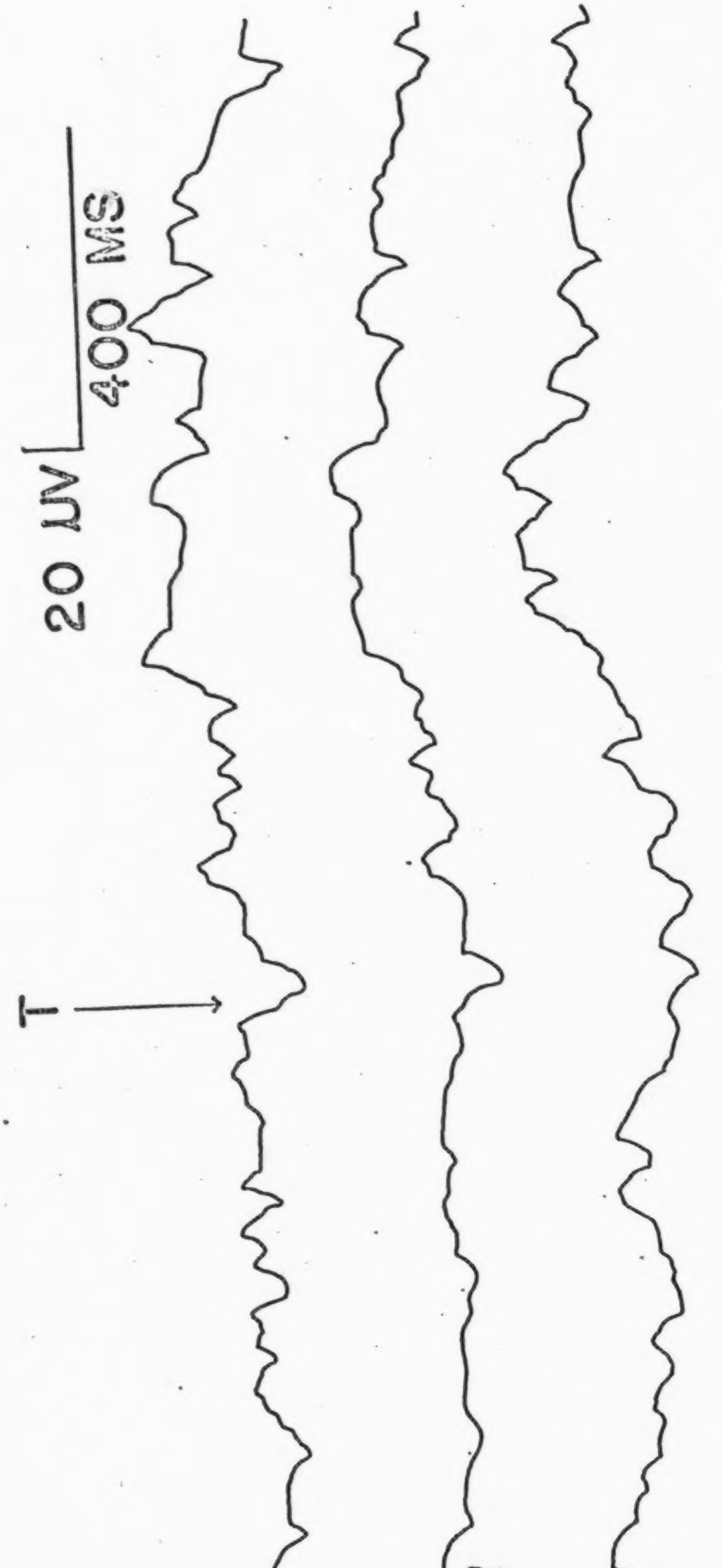
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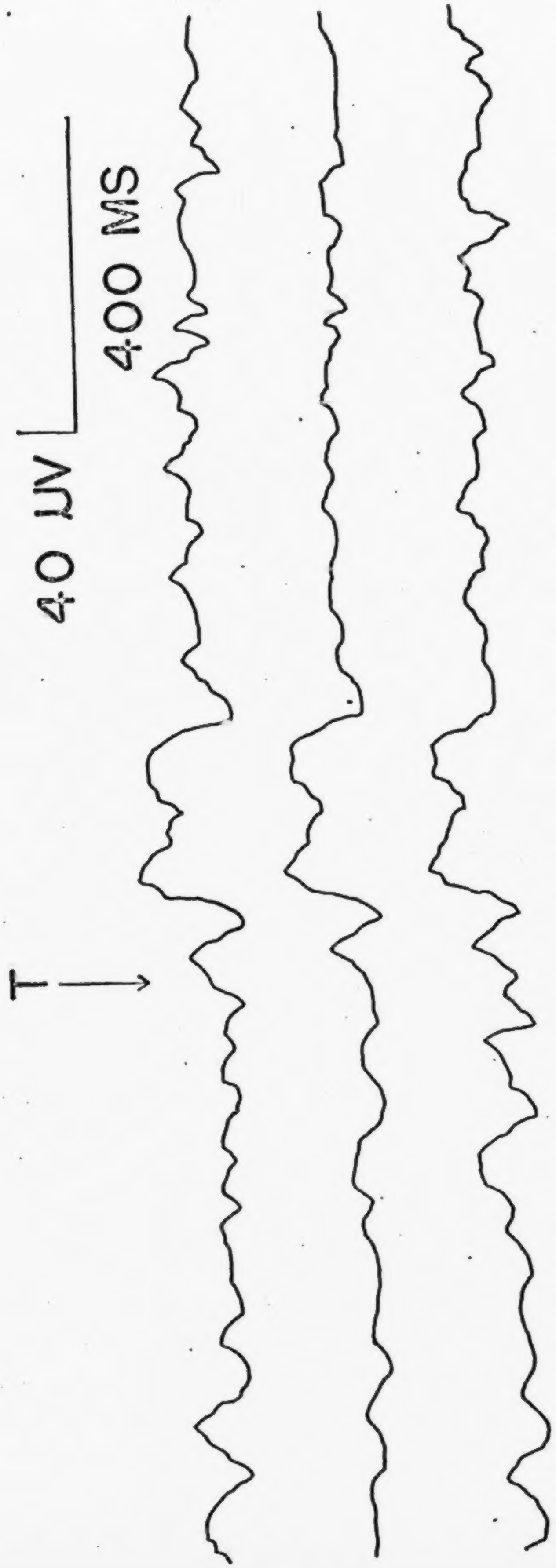
Fig. 2. Averaged parietal EEG to 32 presentations of white noise (subject Kathy). Mean curve is in the middle. Top and lower curves are ±1 standard deviation from the mean.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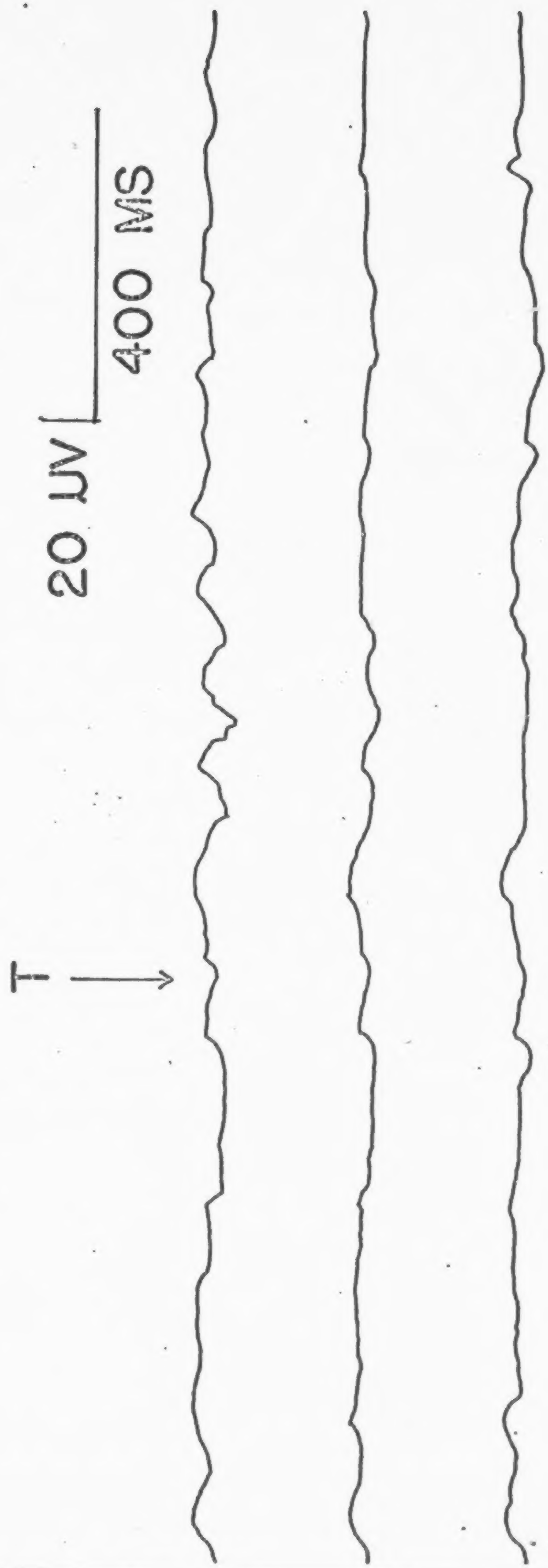
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400 MS
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Table 3

Measured Responses to Stimuli

S Evelyn

	Eye			Lip			Neck			Tongue			Non-arm			EEG Pari			EEG Occip		
Condition	R	B	D	R	B	D	R	B	D	R	B	D	R	B	D	R	B	D	R	B	D
All Words	-2	+1	1	0	-1	-1	-2	-3	-1	+19	-25	-6							-2	-2	0
Low Image																					
Fact	-3	-2	1	-2	+1	1	+9	-8	1	+40	-54	-14							+5	-2	3
Mind	-2	+1	1	-1	+1	0	-1	-5	-4	+36	+25	11							-12	-4	8
High Image																					
Girl	-1	+2	-1	-2	-2	0	-5	-3	2	+52	+58	-6							-12	-8	4
Car	-2	+2	0	-1	+1	0	+4	-3	1	-40	-51	-11							+8	-4	4
Noise	-2	+2	0	0	0	0	+4	-3	1	-25	+35	-11							-26	-10	16

Note.—R refers to the response period, the 400 ms following the trigger. B refers to the baseline period, the first 400 ms of each trace. R and B values are the greatest monotonic potential shift (amplitude) in each period. The signs refer to the direction of the measured potential shift. D values are the absolute value of R minus the absolute value of B.

S Jean

	Eye			Lip			Neck			Tongue			Non arm			EEG Pari			EEG Occip		
Condition	R	B	D	R	B	D	R	B	D	R	B	D	R	B	D	R	B	D	R	B	D
All Words	+6	-4	2	-5	-8	-3	-2	-2	0	-4	-2	2	-3	+3	0	-10	-2	+8			
Low Image																					
Fact	+3	-6	-3	-18	+14	-4	-4	-6	-2	+8	-7	1	+5	-5	0	-28	-10	+28			
Mind	+8	-6	2	-14	+17	3	+4	-8	-4	+4	-10	-6	-9	-9	0	-16	-6	+10			
High Image																					
Girl	+11	-7	4	-18	+15	-3	-7	+4	3	-6	-4	2	-4	-5	-1	+18	+18	0			
Car	+14	-14	0	-9	+12	3	-6	-6	0	+6	-8	-2	+6	+8	-2	-8	-10	-2			
Noise	+7	-6	1	+19	+15	4	-4	-5	-1	+7	+6	-1	-5	+9	-4	-26	-12	+14			

S̲ Kathy

Condition	Eye			Lip			Neck			Tongue			Non arm			EEG Pari			EEG Occip		
	R	B	D	R	B	D	R	B	D	R	B	D	R	B	D	R	B	D	R	B	D
All words	+2	+2	0	+1	0	1	+4	+7	-3	+1	+3	-2	-1	-1	0	-7	-6	1	-17	-14	3
Low Image																					
Fact	-2	-4	-2	+2	-2	0	-10	-7	3	-3	-4	-1	+3	-4	-1	-12	+12	0	+28	-28	0
Mind	+2	+5	-3	+3	-2	1	-5	-10	-5	+4	+7	-3	-2	+2	0	-19	-13	6	-36	-16	20
High Image																					
Girl	+4	+2	+2	+2	-2	0	+5	-10	-5	+3	+3	0	-3	-4	-1	-19	-14	5	-22	-28	-6
Car	+4	+4	0	+5	-5	0	+4	+8	-4	+4	-4	0	+4	-2	2	+14	+14	0	+34	+12	22
Noise	-4	-4	0	-4	-3	1	+7	+8	-1	-2	-3	-1	-3	-4	-1	-19	+10	9	+34	-14	20

S Virginia

Condition	Eye			Lip			Neck			Tongue			Non arm			EEG Pari			EEG Occip		
	R	B	D	R	B	D	R	B	D	R	B	D	R	B	D	R	B	D	R	B	D
All Words	+2	+4	-2	0	0	0	0	0	0	+10	+6	+4	0	-1	-1	-7	-7	0			
Low Image																					
Fact	-9	+8	+1	-1	-2	-1	-2	+2	0	+9	+10	-1	-2	-2	0	-16	-12	4			
Mind	-6	-8	-2	-3	+5	-2	+1	-2	-1	+9	-14	-5	-3	+3	0	-18	+8	10			
High Image																					
Girl	+4	-3	+1	-1	-2	-1	-1	+2	-1	+9	+16	-7	-5	+3	2	+10	+16	-4			
Car	-4	+21	-17	+2	-2	0	-3	+2	1	+19	-11	8	-4	+4	0	+8	+16	-8			
Noise	-2	-2	0	+2	-2	0	-1	-2	-1	+10	+10	0	+4	-3	1	+4	+12	-8			

S William

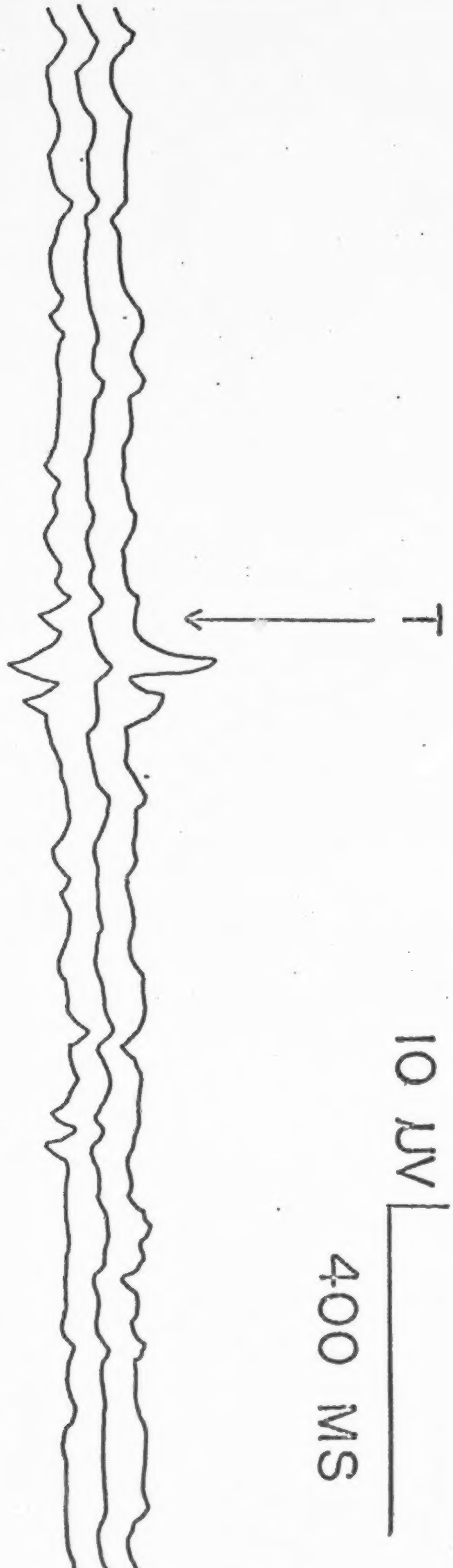
	Eye			Lip			Neck			Tongue			Non arm			EEG Pari			EEG Occip		
Condition	R	B	D	R	B	D	R	B	D	R	B	D	R	B	D	R	B	D	R	B	D
All Words	-3	+4	-1	+1	-2	-1	+1	+1	0	-4	-3	1	-2	-1	1	-16	-6	10	-10	+6	4
Low Image																					
Fact	-3	+5	-2	+1	-1	0	+2	+2	0	+3	-9	6	+7	+3	4	+21	+20	1	-12	+9	3
Mind	+7	+10	-3	+3	+2	1	-2	-2	0	+9	-8	1	+2	+4	-2	-24	-14	10	-14	-10	4
High Image																					
Girl	+7	+8	-1	-2	-2	0	-2	+4	-2	+6	-7	-1	-6	+4	2	-14	+8	6	-23	-10	13
Car	+7	-9	-2	+6	-11	-5	+3	+4	-1	+11	+13	-2	-3	+3	0	+20	+20	0	-20	+17	3
Noise	+9	-4	5	-4	-4	0	-3	+3	0	+7	-9	-2	-5	-3	2	-36	+16	20	-44	-16	28

Table 4

Reaction Changes to Stimuli

	Measure					EEG	
Condition	Eye	Lips	Neck	Tongue	Non Arm	Occipital	Parietal
All Words							
SE	1	-1	-1	-6		0	
SJ	2	-3	0	2	0		8
SK	0	1	-3	-2	0	3	1
SV	-2	0	0	4	-1		0
SW	-1	-1	0	1	1	4	10
$\bar{X}$	0	-.8	-.8	-.2	0	2.3	4.8
Noise							
SE	0	0	1	-11		16	
SJ	1	15	-1	-1	-4		14
SK	0	1	-1	-1	-1	10	20
SV	0	0	-1	0	1		-8
SW	5	0	0	-2	2	28	20
$\bar{X}$	1.2	3.2	-.4	-3.0	-.4	18.0	11.5

Fig. 3. Averaged arm EMG to 32 presentations of the word "car" (subject Virginia). Mean curve is in the middle. Top and lower curves are ±1 standard deviation from the mean.


T
10 µV
400 MS

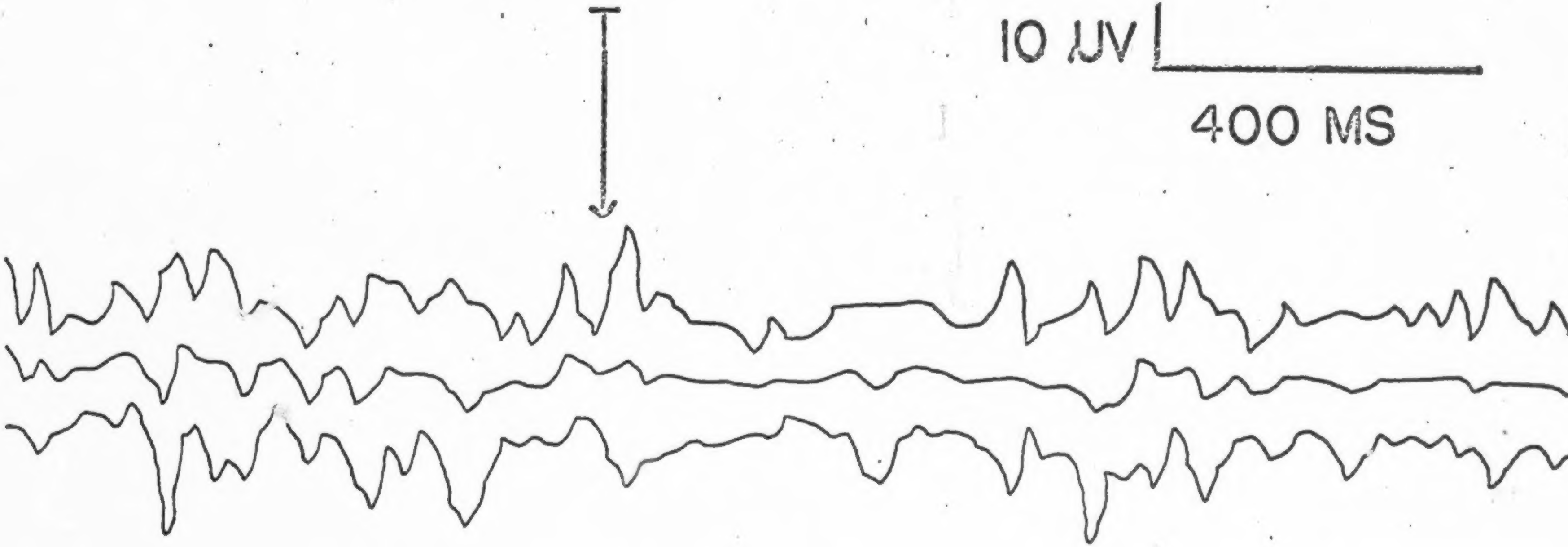
but the latter are small, and their latencies vary widely. However, the relative paucity of EMG responses should not be taken to infer that EMG responses to not occur. EMG responses are typically of relatively high frequency (several hundred Hz. and above) and of very short duration (several milliseconds). The computer sampling rate was set for the relatively slow EEG and eye responses, and may thus have missed responses in muscles. (Since the sampling rate was 100 data points per second, the trace cannot be expected to reproduce waveforms of greater frequency than about 50 Hz.)

With regard to response differences as a function of imagery power of the words, the date of Table 4 are essentially negative. That is, while one can tease out several suggestions, there is no consistent indication that any of the amplitude measures differentiate between the two classes of words.

One interesting, though not entirely general, finding is a depression effect in tongue activity following simuli. The effect is quite consitent for some subjects but not for others. An illustration is presented in Figure 4.

In conclusion, it seems that both white noise and auditory verbal stimuli evoke cortical-evoked potential, but there is no evidence of a systematic relationship with class of word when categorized as a function of imagery. Relatively few responses were recorded to stimuli in any of the muscle or eye areas measured, though this is probably due to limitations in measurement procedures.

Fig. 4. Averaged tongue EMG to 32 presentations of the word "mind" (subject Jean). Mean curve is in the middle. Top and lower curves are ±1 standard deviation from the mean.


10 µV
400 MS

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COVERT PSYCHOPHYSIOLOGICAL RESPONSES AND LANGUAGE PROCESSING

Abstract

The general problem of the relationship between covert physiological responses and "mental" processes was expressed in terms of three specific questions:

(1) Are there increases in covert oral activity as a concomitant of "mental" activity or thinking in a human subject?

(2) Are covert oral activity increases during thinking actually language-related?

(3) Is there any detectable invariance in EMG or EEG activity for repeated pronunciations of the same word and can this same invariance be detected as one listens to that same word?

In an attempt to answer these questions, four channels of electromyographic (EMG) data and two channels of electroencephalographic (EEG) data were collected from each of two subjects (data from a third subject had to be discarded) as they were exposed to 40 repetitions each of three auditory stimuli (two verbal and one non-verbal) during three experimental conditions.

The data were processed and analyzed by the use of a computer signal averaging program. The largest and most consistent activity increases during language processing conditions were found in the preferred arm EMG. The lip EMG showed sufficiently distinctive activity patterns during overt pronunciation of words to differentiate between the words pronounced; however, there was no such distinctive pattern for any EMG response during the hearing of the same words.

The oral EMG response was essentially the same whether the subject was presented with a verbal or non-verbal auditory stimulus; however, oral responding was generally higher than non-oral control measure responding

even during the presentation of non-verbal auditory stimulation. Possible explanations for the experimental findings were presented.

COVERT PSYCHOPHYSIOLOGICAL RESPONSES AND LANGUAGE PROCESSING

The topic of covert oral activity and its relationship, if any, to "mental" processes such as thinking comprises a number of distinct questions. This study, directly or indirectly, has potential bearing on several of these questions, among which are the following:

1. Are there increases in covert oral activity as a concomitant of "mental" activity or thinking in a human subject.

In the present study, the question was whether covert oral activity as measured by electromyograms (EMGs) and brain wave activity as measured by electroencephalograms (EEGs) increased significantly over a resting baseline during mental activity which includes the processing of certain verbal stimuli. This mental activity was presumed to occur as the result of instructions to attend to and in some cases, reproduce those verbal stimuli.

In attempting to answer this question, a comparison was made of oral muscular activity of the subjects at rest versus oral activity when the subjects were listening to verbal stimuli. Further, the amplitude of any increases in oral activity was compared with that of any increases found in the control measure, the right leg.

2. Are covert oral activity increases during thinking actually language-related?

In attempting to answer this question, it may be that one gets very specific kinaesthetic feedback from his covert oral activity; i.e., this activity may be actual speech activity, and that, therefore, it is reasonable to look for qualitative similarities between covert and overt pronunciation of the same word or phrase.

However, it may be unreasonable, because of the probable short-circuiting which occurs, to expect to find anything so specific about covert oral activity as an individual motor gesture which is related to a given phoneme. Rather, a distinction between speech and non-speech oral activity on the basis of such a feature, as, for example, the relative presence or absence of lip activity while the subject is processing labial phonemes.

In terms of the present study, an attempt was made to answer the question of the speech-relatedness of any covert oral activity increases observed by comparing the responses made to verbal stimuli with those made to non-verbal white noise. Further, a comparison was made of the lip and chin activity while listening to an initial labial phoneme stimulus ("peep") with that activity while listening to an initial non-labial phoneme stimulus ("leap"). It was expected that the overt pronunciations of these words would confirm the assumption of greater lip activity at the bi-labial onset of "peep."

3. Is there any detectable invariance in EMG or EEG activity for repeated pronunciations of the same word and can this same invariance be detected as one listens to that same word?

The remaining major comparison made in this study was between the subjects' psychophysiological responses while listening to and while producing the same verbal stimulus. This has potential relevance to the competition between the motor and aural theories of speech perception. These theories have stimulated considerable research; e.g., Goto (1968), Hintzman (1967), Locke (1969), McCroskey (1958), and Ringel (1963) as to the relative contribution of kinaesthetic and auditory cues to the production and perception of speech. Wyczoikowska (1913) adumbrated the modern motor theory of speech perception with her statement that ". . . one does not completely understand the word that is spoken to him until it is repeated by his own organ of speech (although in a more simple way) (p. 451)." Currently, Liberman (1962, 1967) is the principal spokesman for a motor theory which holds that muscular contractions (or the motor neural correlates of these contractions, as Liberman later modified the theory) which are invariant for the production of sub-phonemic or phonemic units of language also mediate the perception of language process. Therefore, according to a motor theory, it is these production-related muscular activities and not the acoustic signals which are the vital cues in speech perception.

Of course, before this hypothesized mediating function of production-related cues can be tested, the prior hypothesis of invariance of muscular activity during production of language must be verified. Fromkin (1966) attempted such a verification, but failed to find a simple correspondence between the production of given phonemes and activity of the orbicularis oris muscle. She suggested, therefore, that the minimal linguistic unit corresponding to a motor command may be larger than the phoneme; i.e., the syllable.

MacNeilage (1964), on the other hand, used surface electrodes at 13 different locations on the tongue of one subject and found distinct and reliable activity patterns at the various electrode sites for each vowel sound produced.

In the present study, invariance of muscular or neural activity was tested for during the repeated pronunciation of each of the two words "leap" and "peep." A final possible comparison was of the subject's psychophysiological activity while hearing a word with his activity while pronouncing that same word.

Method

Subjects. The subjects were a seven-year-old boy and a seven-year-old girl. The age of seven was used because it was assumed language development would have advanced sufficiently in these children to allow them to participate in the experiment and because, on the other hand, following the suggestion of researchers such as Edfeldt (1960, Sokolov (1969), and Luria (1961, 1969), it was assumed that amplitude of covert oral responses made by these children would be sufficiently large to facilitate measurement and comparisons. Each child was paid $1.00 for participating in the experiment.

Apparatus: One audio magnetic tape was recorded for each subject. It included general instructions, relaxation instructions, and then specific instructions, a practice session, and the auditory stimuli for each of the three experimental conditions--Repeat Aloud, Repeat in a Whisper, and Listen Only. Each experimental condition included a randomized presentation of 40 of each of the three auditory stimuli ("leap"--the verbal stimulus which begins with a dental-alveolar phoneme; "peep"--which begins with a bi-labial phoneme; and the non-verbal stimulus, white noise; hence, there was a total of 360 stimuli for each subject. The inter-stimulus interval was approximately 5-sec. The tape was played for each subject through a speaker placed on the floor directly in front of a comfortable chair in which he was seated. The apparatus and subject rooms were completely shielded to eliminate extraneous radio and magnetic frequency signals.

Surface electrodes were attached to the upper left and lower right corners of the lips and following Davis (1952), to the chin, preferred arm, and the right leg as a control. Surface electrodes were attached to the scalp at locations C_3 and T_5 of the International Electrode Placement System.

The EMG and EEG impulses were amplified 10,000 times during the repeating aloud and whispering conditions and 100,000 times for the listening only condition. The amplified signals were then recorded on separate channels of a data tape recorder on magnetic tape running at a speed of 7 1/2 inches per second. The experimental stimuli and the subjects' responses to them were recorded on the data tape recorder concurrently with the electrical signals.

Design. The three experimental conditions were presented in an incompletely counterbalanced design; that is, subject 1 received order A-B-C, subject 2 order B-C-A, and subject 3 order C-A-B. As Underwood (1966) notes, this incompletely counterbalanced design, while not including all possible orders of the conditions, does avoid confounding due to practice effects because each condition occurs equally often at each stage of practice.

Procedure. After the subject was seated and the electrodes were applied, he was told that he would hear all necessary instructions from the speaker. The lights were dimmed considerably to eliminate responses to visual stimuli as much as possible. Due to the age of the subjects, each was asked if he desired someone to sit in the room with him; subject 2 requested that this be done.

In the general instructions at the beginning of each tape, the subject was told the exercise had three parts and that he would be given instructions on what to do in each part and then asked to relax as much as possible. He was told what to do in Part A and then given six stimuli for practice. Following these instructions, the subject heard very extensive relaxation instructions, after which he rested for 60-sec. Part A of the experiment then began. Before each of the two subsequent parts of the experiment, the subject again received detailed instructions and practice stimuli.

The counterbalanced conditions were as follows:

In part A, the verbal stimuli were presented in a normal speaking voice and the subject was instructed to repeat each word aloud as soon as he heard it. He was instructed to listen to the white noise, which was set at approximately the same decibel level as the voice.

In part B, the verbal stimuli were presented in a whispered voice and the subject was instructed to repeat each word in a whisper as soon as he heard it. The same instructions as in part A held for the white noise.

In part C, the verbal stimuli were presented in a normal speaking voice and the subject was instructed to listen only to all stimuli--both verbal and non-verbal.

Following the third condition, the subject was asked to relax as completely as he had at the beginning of the experiment, again for a 60-sec. period. These relaxation periods were used to obtain baseline measurements for the subjects' psychophysiological reactions.

Quantification of the data. The EMG signals were rectified and the EEG signals reduced by the use of resistors and then all signals were fed into a Digital Equipment Corporation PDP 8/1 computer. The Digital Equipment Corporation signal averaging program used allows one to extract a signal from noise, since the signal is reinforced throughout the averaging process; while the noise, with random plus and minus values, is reduced.

The program requires the experimenter to generate control tapes which specify such parameters as the number of channels of data which will be averaged in a single run, the length of the signal to be averaged, the number of discrete data points to be sampled during each averaging period, the number of sweeps of each particular signal, and the nature of the signal which triggers the computer to begin averaging. For this particular experiment, two control tapes were generated. This is indicative of the fact that we were interested in two basic phenomena; namely, the subjects' psychophysiological reactions while pronouncing certain words, and secondly, psychophysiological reactions while merely listening to the words. In both cases the auditory signal was the trigger for the computer to begin averaging. In the former instance, the trigger signal was the sound produced by the subject himself. Since several studies have shown that EMG activity connected with the production of audible speech begins in the neighborhood of 400-ms. before the onset of the sound, (Faaborg-Anderson and Edfeldt, 1958; Fromkin, 1966) the control tape instructed the computer to trigger backward 400-ms. from the onset of the auditory signal.

Two channels were processed at one time, with the total length of the sweep set at 800-ms. This allowed the computer to sample 250 data points during each of the 40 sweeps for a given stimulus.

For those responses made while listening to a stimulus, the onset of the taped auditory signal was the trigger, with no backward action. Again, two channels were processed at a time. The total length of the sweep was set a 600-ms., there were 187 data points sampled per response, and there were 40 sweeps for each stimulus.

An X-Y Plotter was driven by the computer. It plotted out the averaged curve plus the 95% confidence limits for each subject's psychophysiological reactions during each condition.

The computer also integrated the area under each of the two halves of the curves to provide a numerical index of the responses made. This resulted in a sum of the averages and a sum of the confidence limits for each half of the sweeps for each condition.

For purposes of data analysis, parts A and B of the experiment were considered to have two sub-sections each; the first the response of the subject upon hearing the verbal stimulus and the second the response of the subject while actually repeating the word. During the processing of the data, it was discovered that part B, the whisper condition, was unusable due to the background noise level on the tape which made it impossible to trigger accurately on the onset of the whispered word; therefore, in terms of the EMG and EEG responses of the subjects which constituted the dependent variables measured, there were the following categories of data:

1. Response while hearing "leap" with instructions to repeat aloud
2. Response while hearing "peep" with instructions to repeat aloud
3. Response while hearing "leap" with instructions to listen only
4. Response while hearing "peep" with instructions to listen only
5. Response while saying "leap" aloud
6. Response while saying "peep" aloud
7. Response while hearing white noise in Listen-Repeat condition
8. Response while hearing white noise in Listen Only condition
9. Response while at rest before Listen-Repeat condition
10. Response while at rest before Listen Only condition

For each measure, a difference between the resting and experimental conditions was computed and this was further changed to a percentage change over rest. There were 192 such figures for each subject (8 conditions X 6 psychophysiological responses X 2 average and 2 confidence limit sums for each psychophysiological response.) These are seen in Figures 1 - 24.

Results and Discussion

In terms of overt activity, against which covert activity was to be compared, the lip of both subject 1 and subject 2 bore out the expectation of greater activity at the bi-labial onset of "peep" as opposed to the non-labial onset of "leap." This can be seen both in the percentage over rest (Figures 1 and 2) and in the average and confidence limit curves drawn on the X-Y Plotter (Figures 3 and 6).

Fig. 1. Percentage Change Over Rest of Averages of EMG Responses for Subject 1 During Repeat Aloud Condition

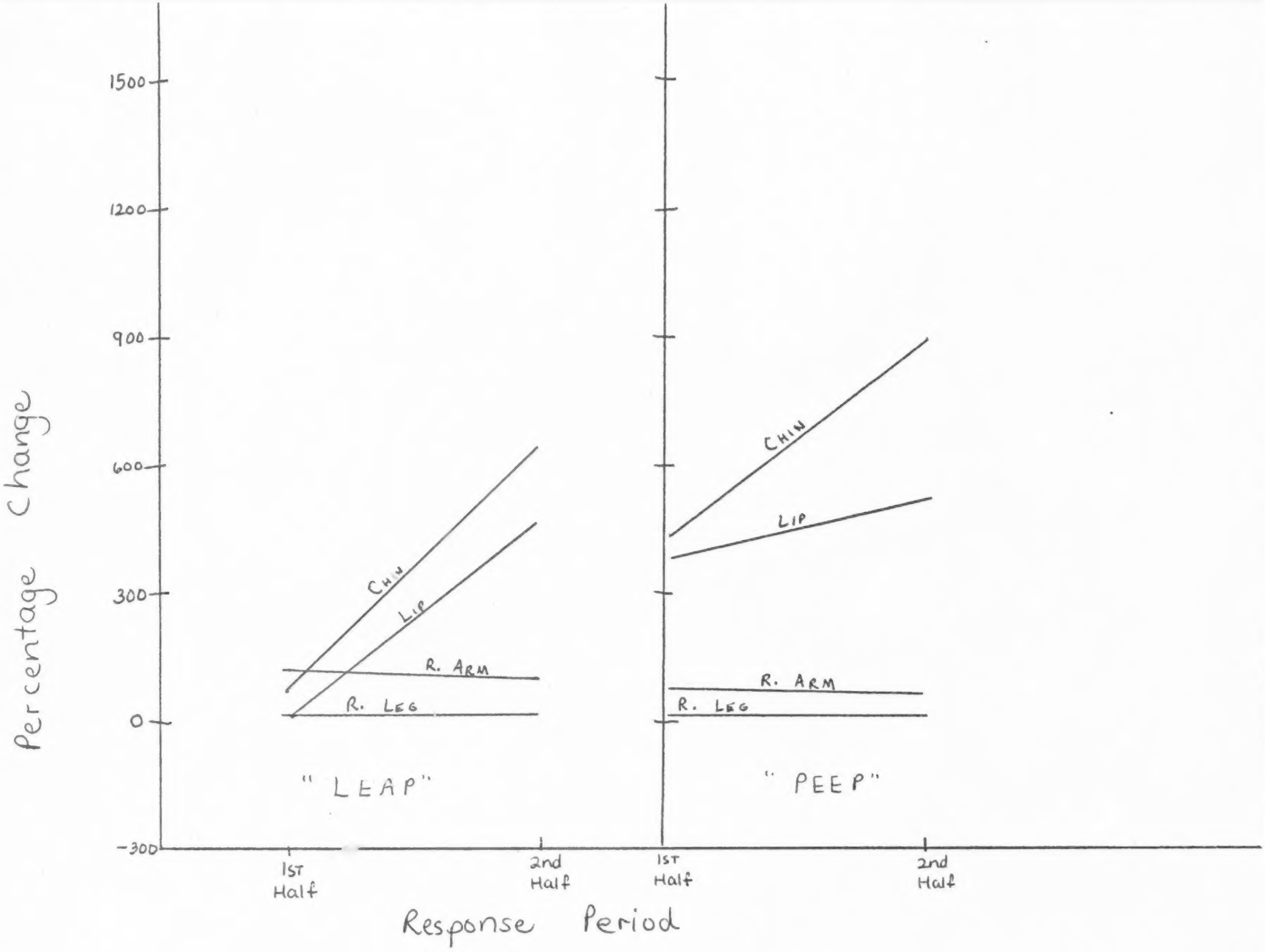

Percentage Change
1500
1200
900
600
300
0
-300
CHIN
LIP
R. ARM
R. LEG
" LEAP"
CHIN
LIP
R. ARM
R. LEG
" PEEP"
1ST Half
2nd Half
1ST Half
2nd Half
Response Period

Fig. 2. Percentage Change Over Rest of Averages of EMG Responses for Subject 2 During Repeat Aloud Condition

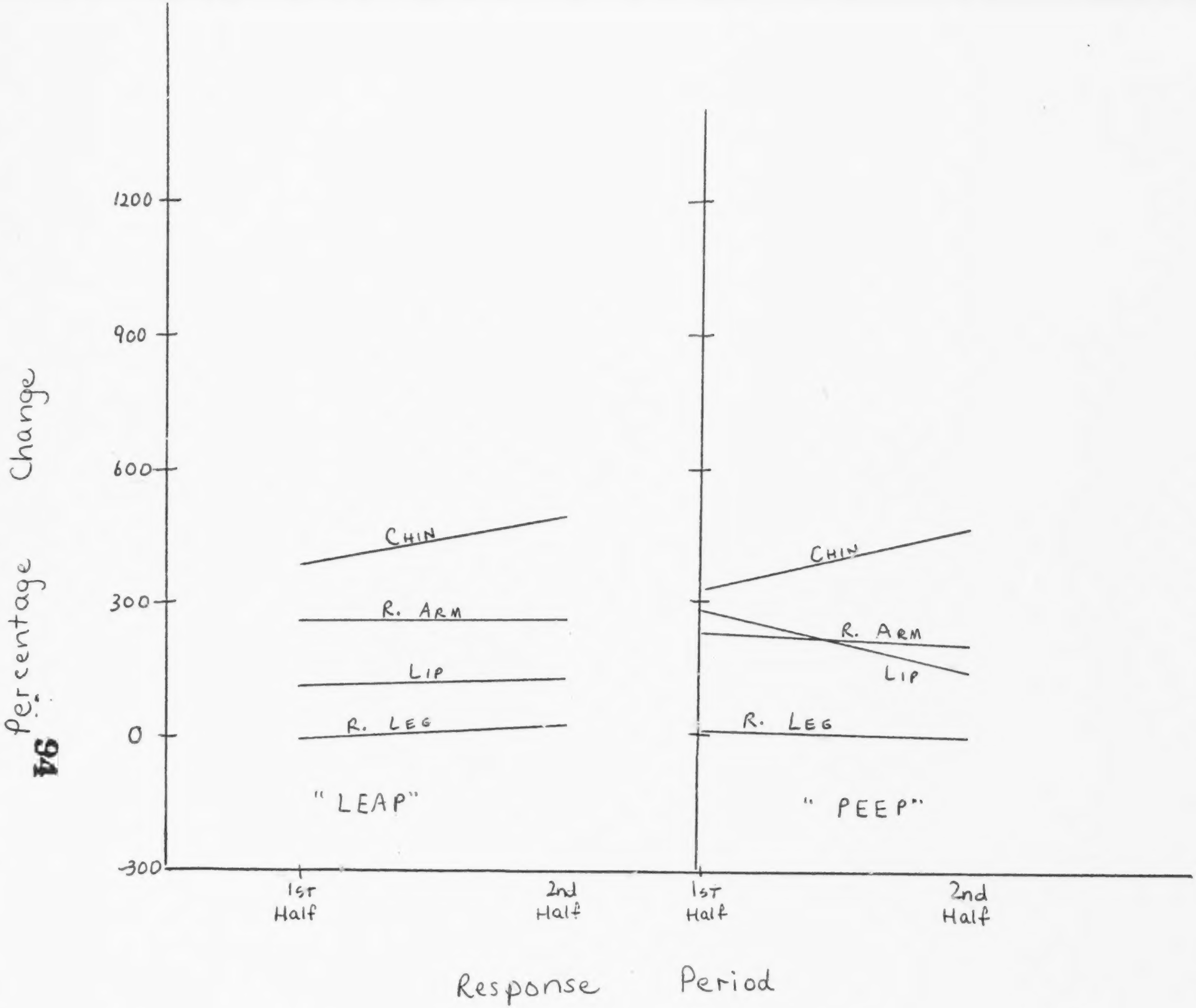

Percentage Change
1200
900
600
300
0
-300
CHIN
R. ARM
LIP
R. LEG
"LEAP"
CHIN
R. ARM
LIP
R. LEG
"PEEP"
1st Half
2nd Half
1st Half
2nd Half
Response Period

Fig. 3. Average and 95% Confidence Limits of Lip EMG for Subject 1 for "Leap" During Repeat Aloud Condition

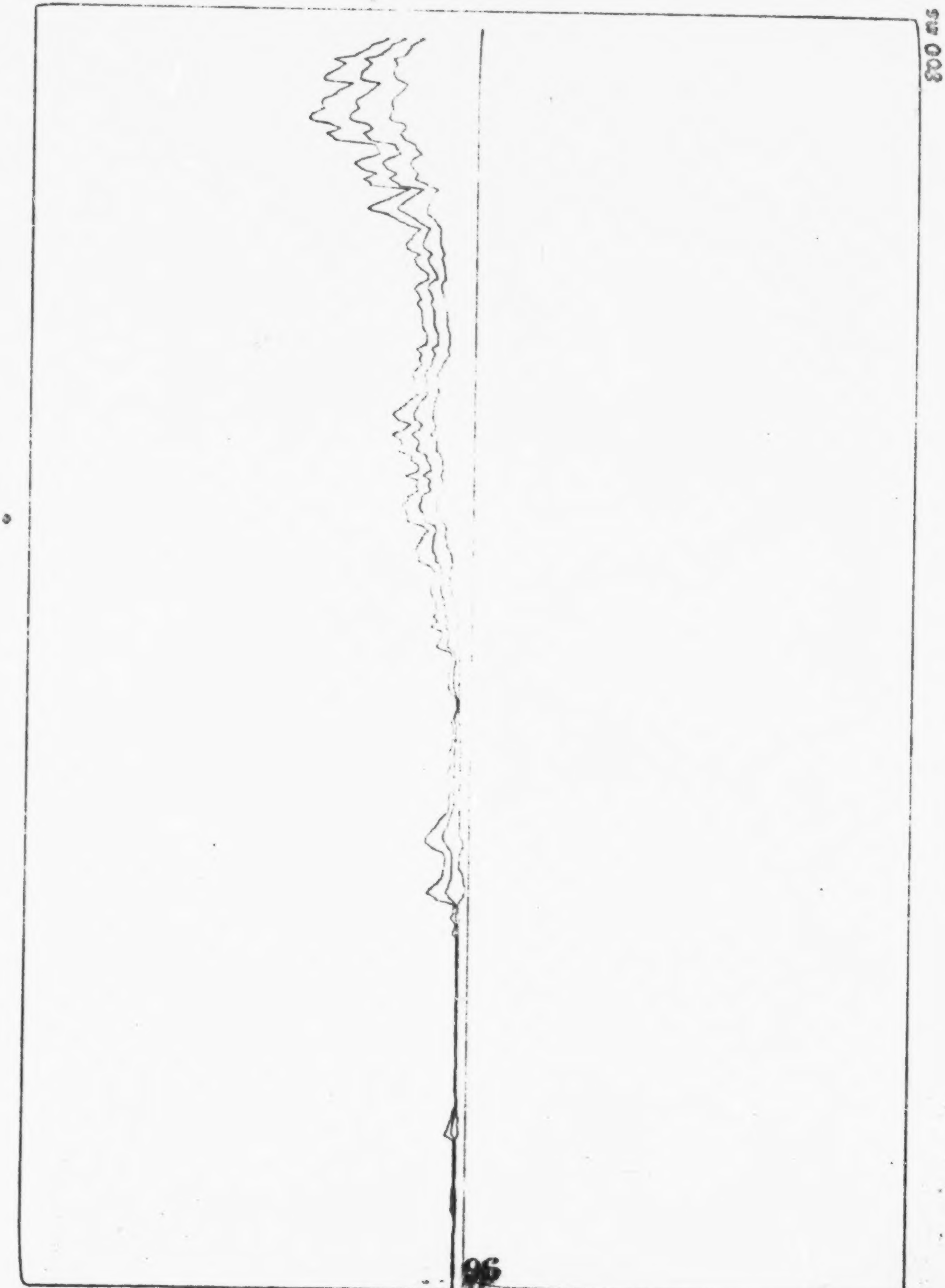

300 ms
5
5

Fig. 4. Average and 95% Confidence Limits of Lip EMG for Subject 1 for "Peep" During Repeat Aloud Condition

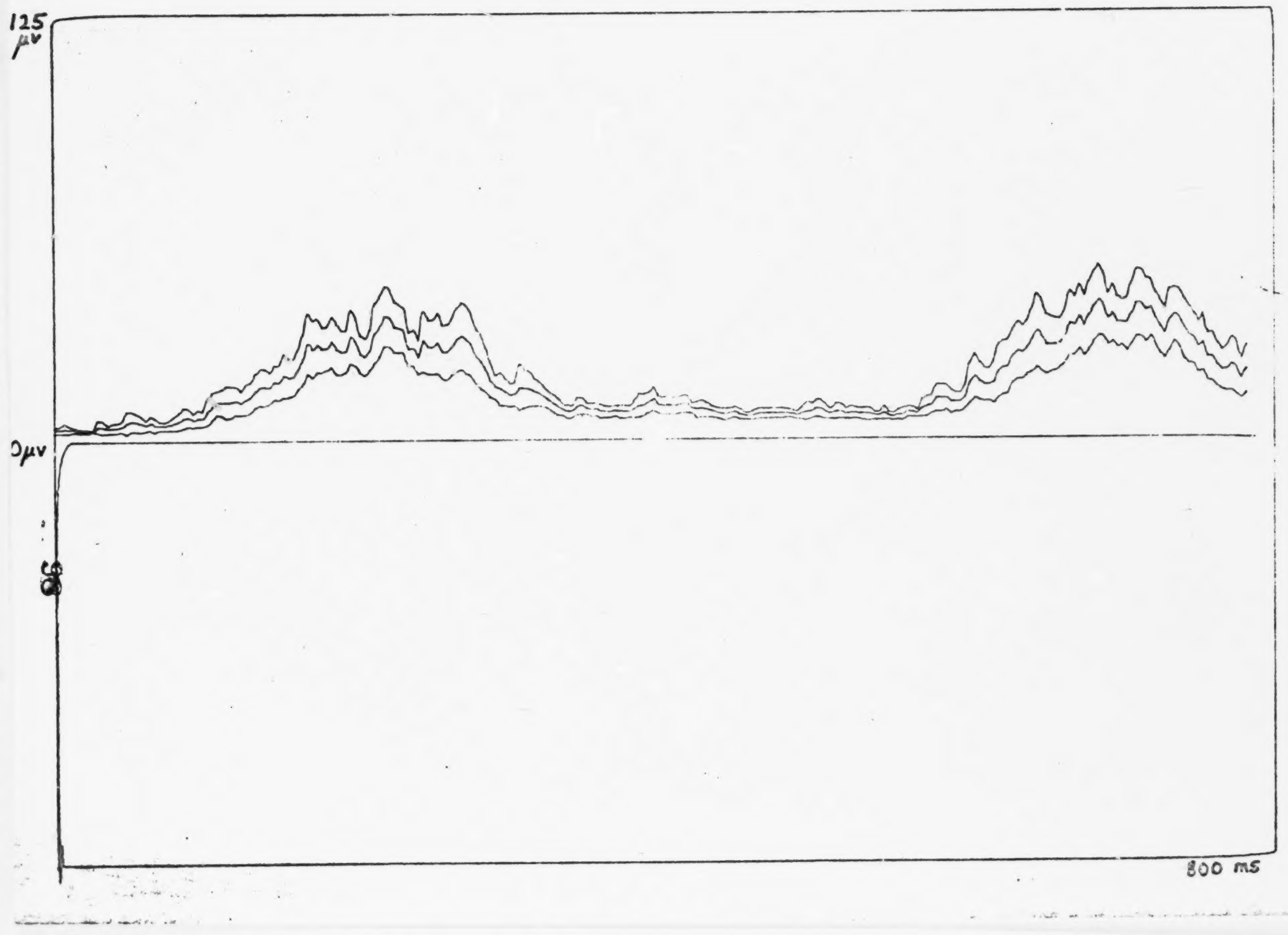

125 µv
0µv
800 ms

Fig. 5. Average and 95% Confidence Limits of Lip EMG for Subject 2 for "Leap" During Repeat Aloud Condition

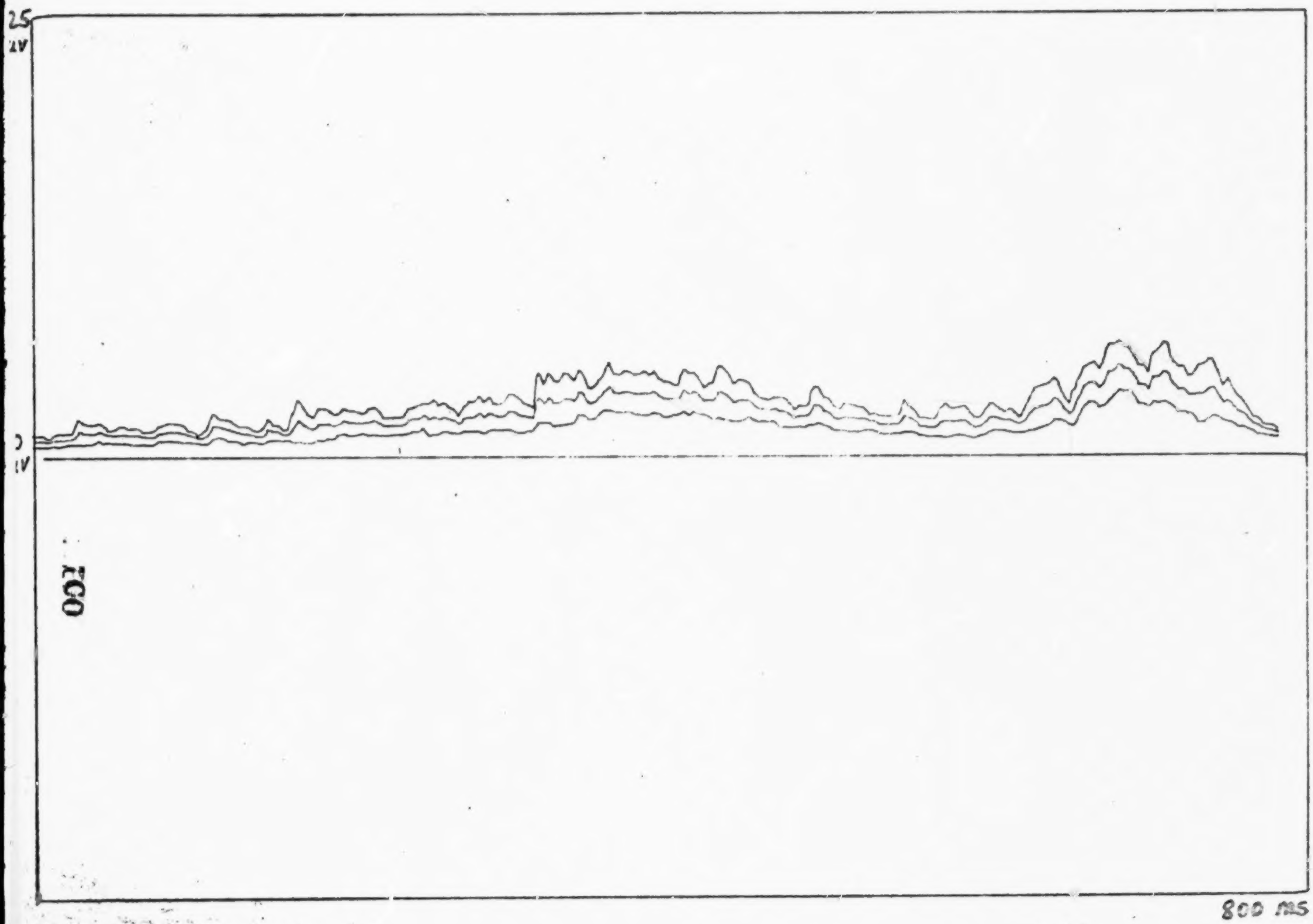
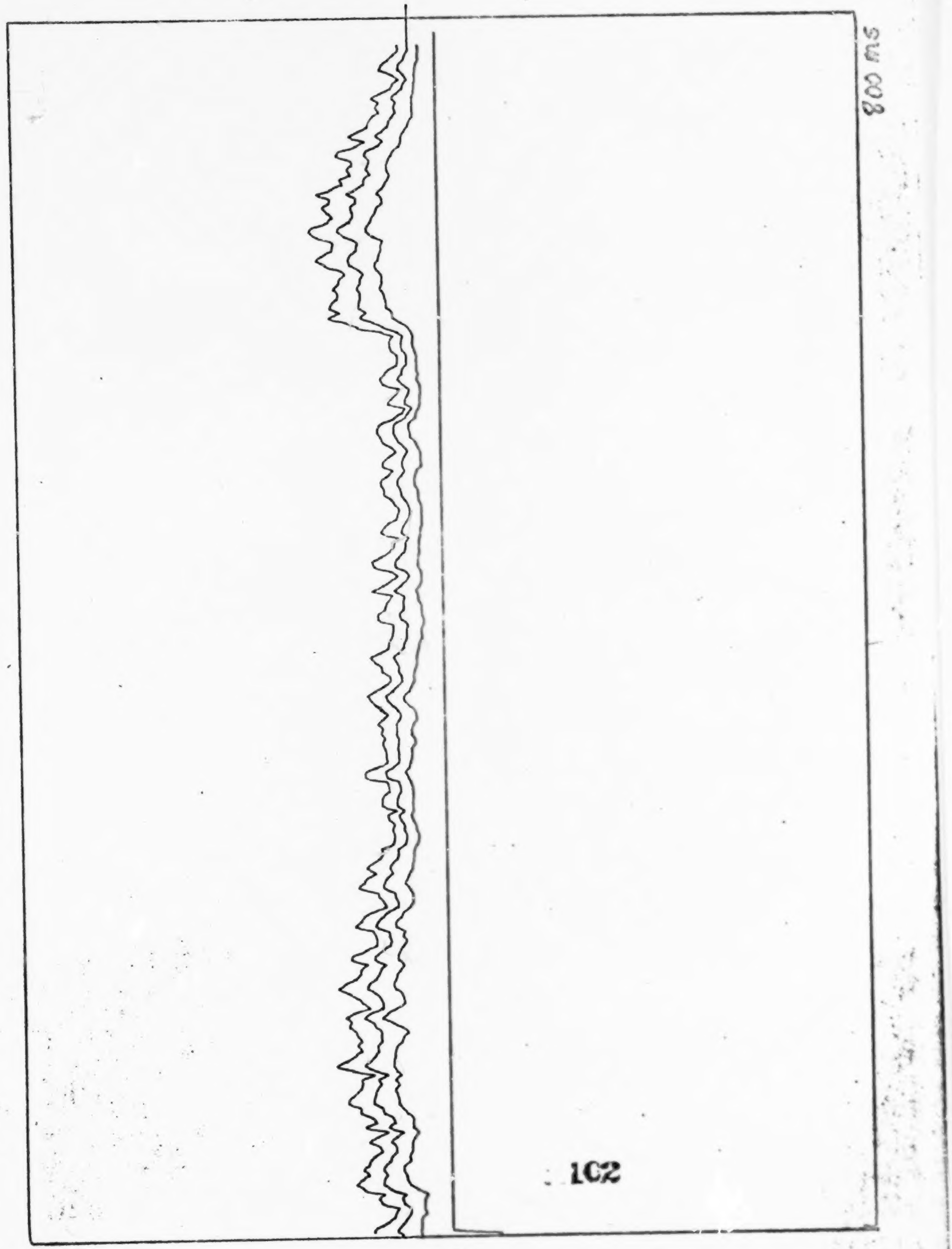

25
μV
0
μV
800 ms
002

Fig. 6. Average and 95% Confidence Limits of Lip EMG for Subject 2 for "Peep" During Repeat Aloud Condition


115 µV
0 µV
800 ms

It can also be noted from Figures 1 and 2 that for subject 1 the chin was similar to the lip in higher activity for the onset of "peep" versus "leap," but for subject 2, this concordance of lip and chin activity did not hold true.

Figures 1 and 2 also show the right leg to be a good control measure for generalized arousal since there was very little change over the resting baseline during the Repeat Aloud condition.

The tracings for the 95% confidence limits (Figures 7 and 8) provide a measure of variability. The chin and lip for subject 1 both show greater variability as well as the greater average activity already mentioned for the onset of "peep" as contrasted with "leap." For subject 2, there was greater variability for the lip for the onset of "peep" versus "leap," but this was not true for the chin. Generally speaking, for the chin and lips, as average activity increased, so did variability; i.e., as seen in the tracings, there was a wider span between the upper and lower confidence limits.

Note, however, that the concordance of increased average activity with increased variability observed in the chin and lips does not hold true for the leg; for whereas the leg was found to be a good control in terms of its averaged activity, it is a poor control in terms of its variability, which in some cases was higher than the variability of the lips, chin, and arm for both subjects, even in the Repeat Aloud condition where the lips and chin would have been their most active. Of course, the chin and lip activity during the overt pronunciation of words follows a fairly prescribed pattern from one repetition to another with resulting limits on variability. Movements of the leg, on the other hand, were probably associated with intermittent random shiftings of the body which entail much more variability in amount of activity from one sampling period to another.

Fig. 7. Percentage Change Over Rest of Confidence Limits of EMG Responses for Subject 1 During Repeat Aloud Condition

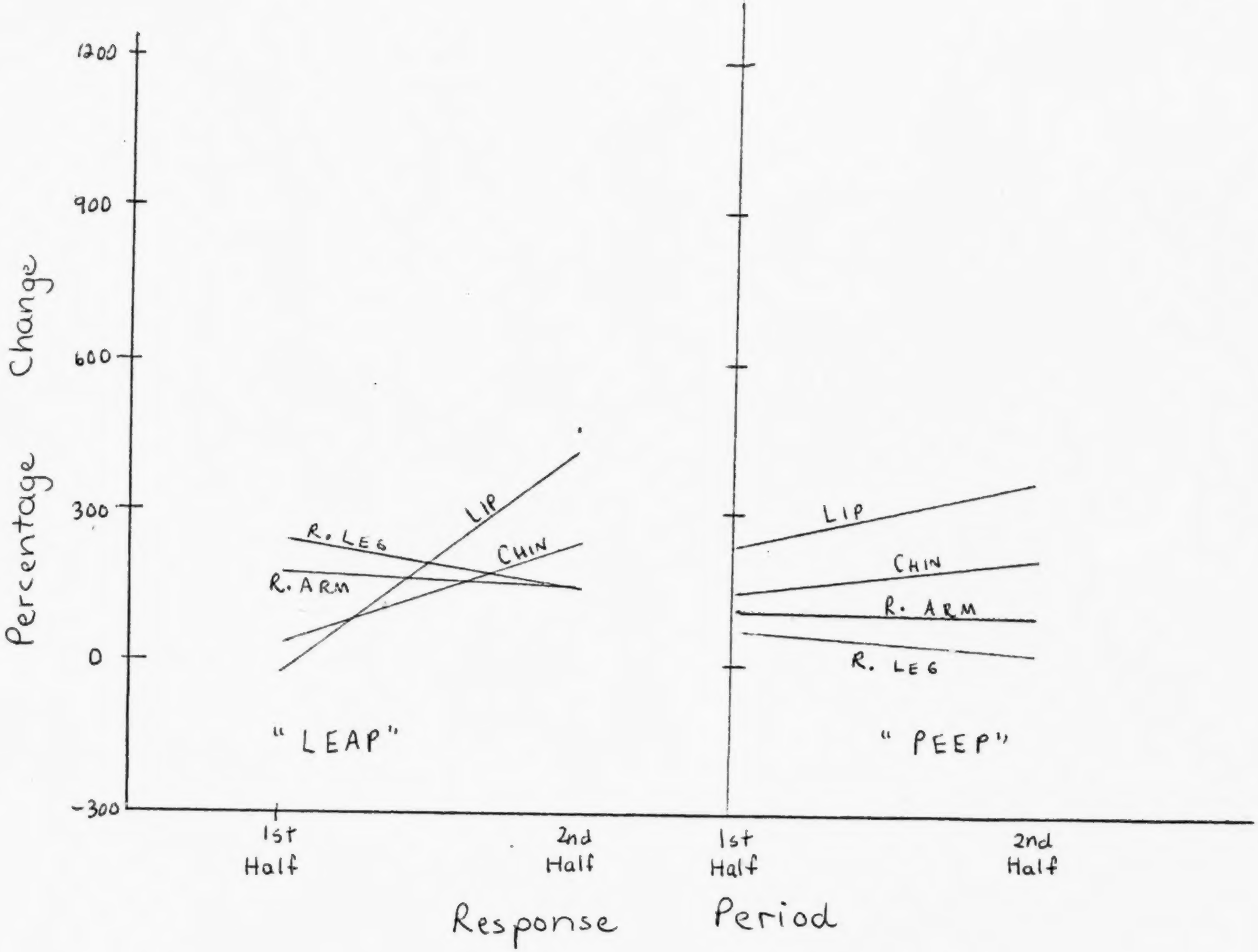
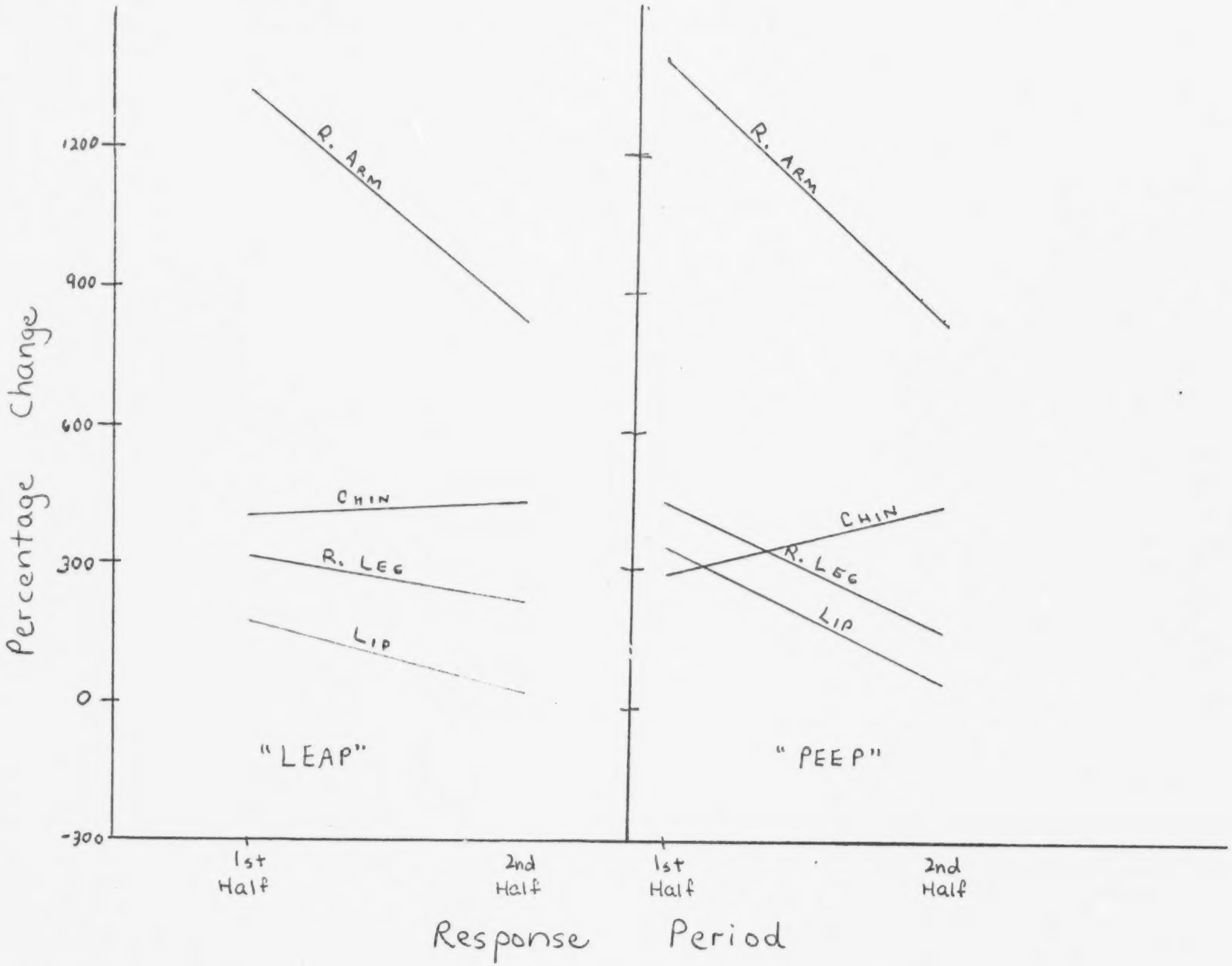

Percentage Change
1200
900
600
300
0
-300
R. LEG
R. ARM
LIP
CHIN
"LEAP"
LIP
CHIN
R. ARM
R. LEG
"PEEP"
1st Half
2nd Half
1st Half
2nd Half
Response Period

Fig. 8. Percentage Change Over Rest of Confidence Limits of EMG Responses for Subject 2 During Repeat Aloud Condition


1200
900
600
300
0
-300
Percentage Change
R. ARM
CHIN
R. LEG
LIP
"LEAP"
R. ARM
CHIN
R. LEG
LIP
"PEEP"
1st Half
2nd Half
1st Half
2nd Half
Response Period

The EEG averages for both subjects during the Repeat Aloud condition showed very little consistency or regularity of pattern except that for subject 2 the auditory EEG averages showed a marked jump in activity relative to rest during the second half of each word. The confidence limits for both EEG measures for both subjects showed very little change relative to rest (Figures 9 - 12).

Looking at EMG activity during the two listening conditions (Listen-Only and Listen-Repeat), it can be seen that for subject 1, the lip was quite high relative to rest in the Listen Only condition while the chin was quite low. In the Listen-Repeat condition, however, the chin was high relative to rest and the lip was low.

For subject 2, the chin and lip showed little or no activity increase and in fact, in most cases, a decrease in activity relative to rest during the Listen Only condition. The lack of activity by these potential indicators of verbal activity is all the more striking when compared with the control measure, the right leg, which in two cases in the Listen Only condition showed a greater percentage increase relative to rest than did the oral measures. In the Listen-Repeat condition for subject 2, only the arm and chin showed consistently more activity relative to rest than did the leg. (Figures 13 - 16).

One very interesting and perhaps the most consistent result of the study was that for both subjects, the preferred arm activity relative to rest was very high during the Listen-Repeat condition, but relatively speaking, quite low in the Listen-Only condition. The arm activity continued to be high during the actual repetition of the word. It might be thought that this arm activity was merely part of the generalized muscular arousal prior to and during repetition of words, but it should be noted that for both subjects, the amount of increase in activity by the arm during

Fig. 9. Percentage Change Over Rest of Averages of EEG Responses for Subject 1 During Repeat Aloud Condition

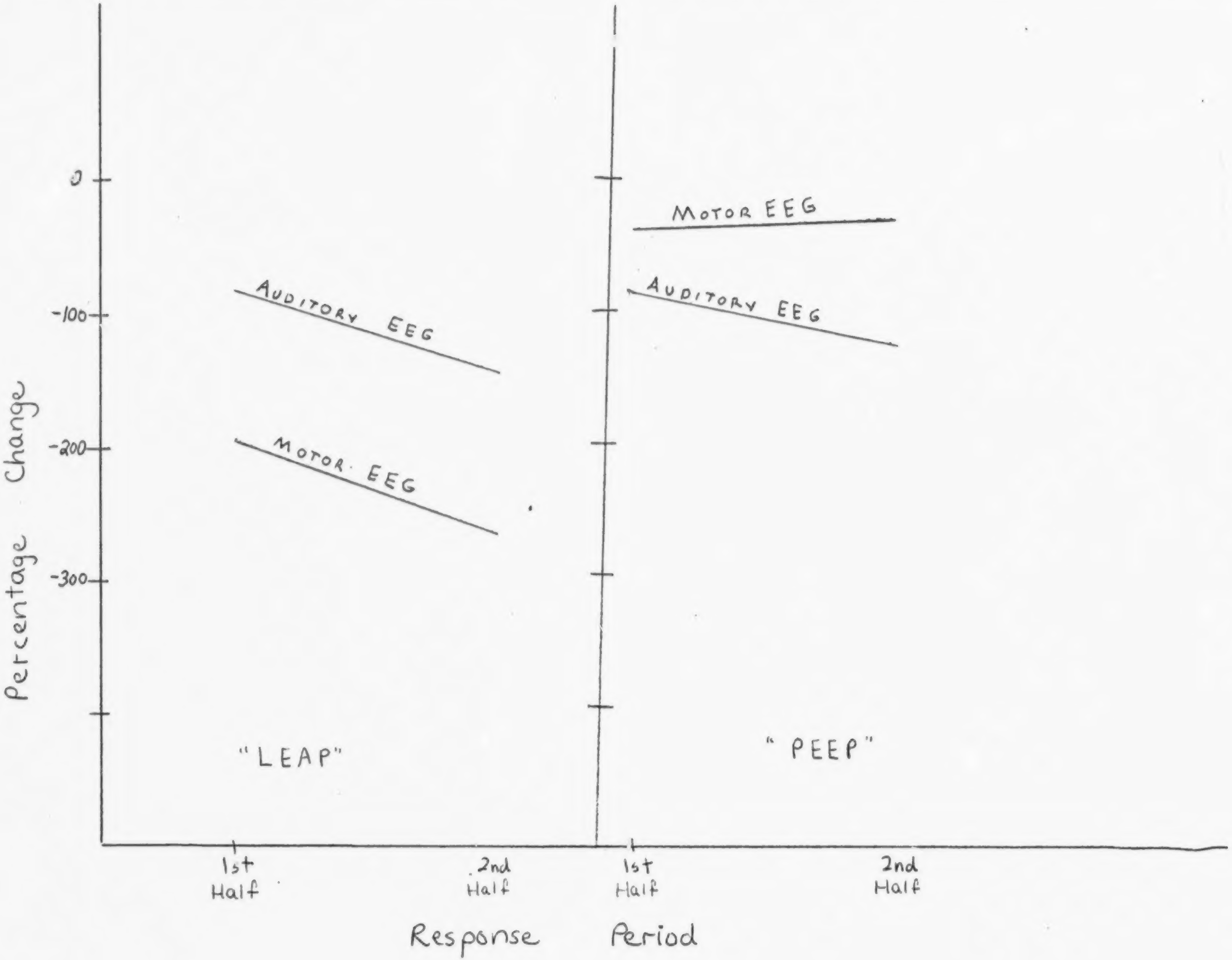

0
-100
-200
-300
Percentage Change
AUDITORY EEG
MOTOR EEG
"LEAP"
MOTOR EEG
AUDITORY EEG
"PEEP"
1st Half
2nd Half
1st Half
2nd Half
Response Period

Fig. 10. Percentage Change Over Rest of Averages of EEG Responses for Subject 2 During Repeat Aloud Condition

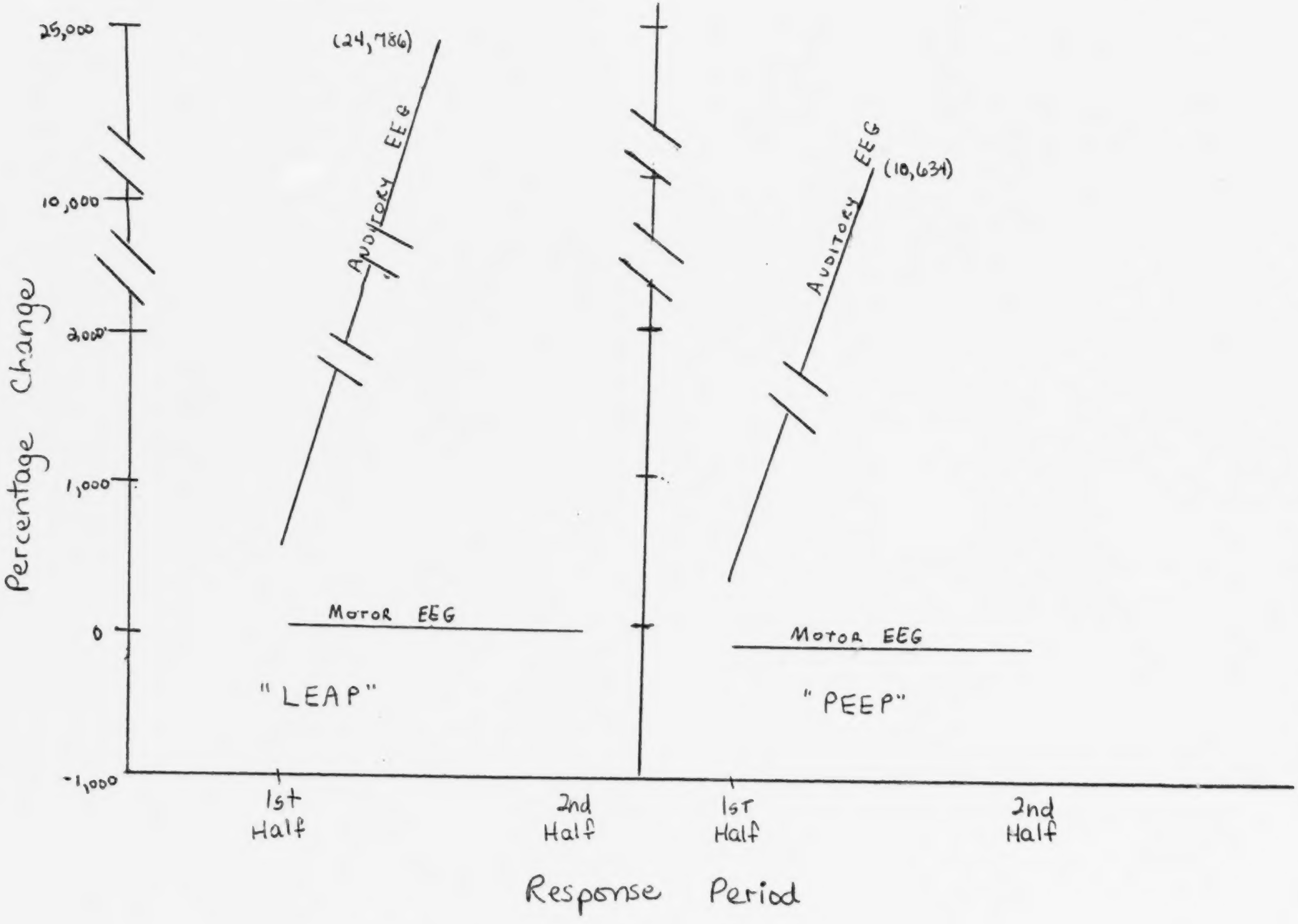

Percentage Change
25,000
10,000
2,000
1,000
0
-1,000
(24,786)
Auditory EEG
Motor EEG
"LEAP"
(10,634)
Auditory EEG
Motor EEG
"PEEP"
1st Half
2nd Half
1st Half
2nd Half
Response Period

Fig. 11. Percentage Change Over Rest of Confidence Limits of EEG Responses for Subject 1 During Repeat Aloud Condition

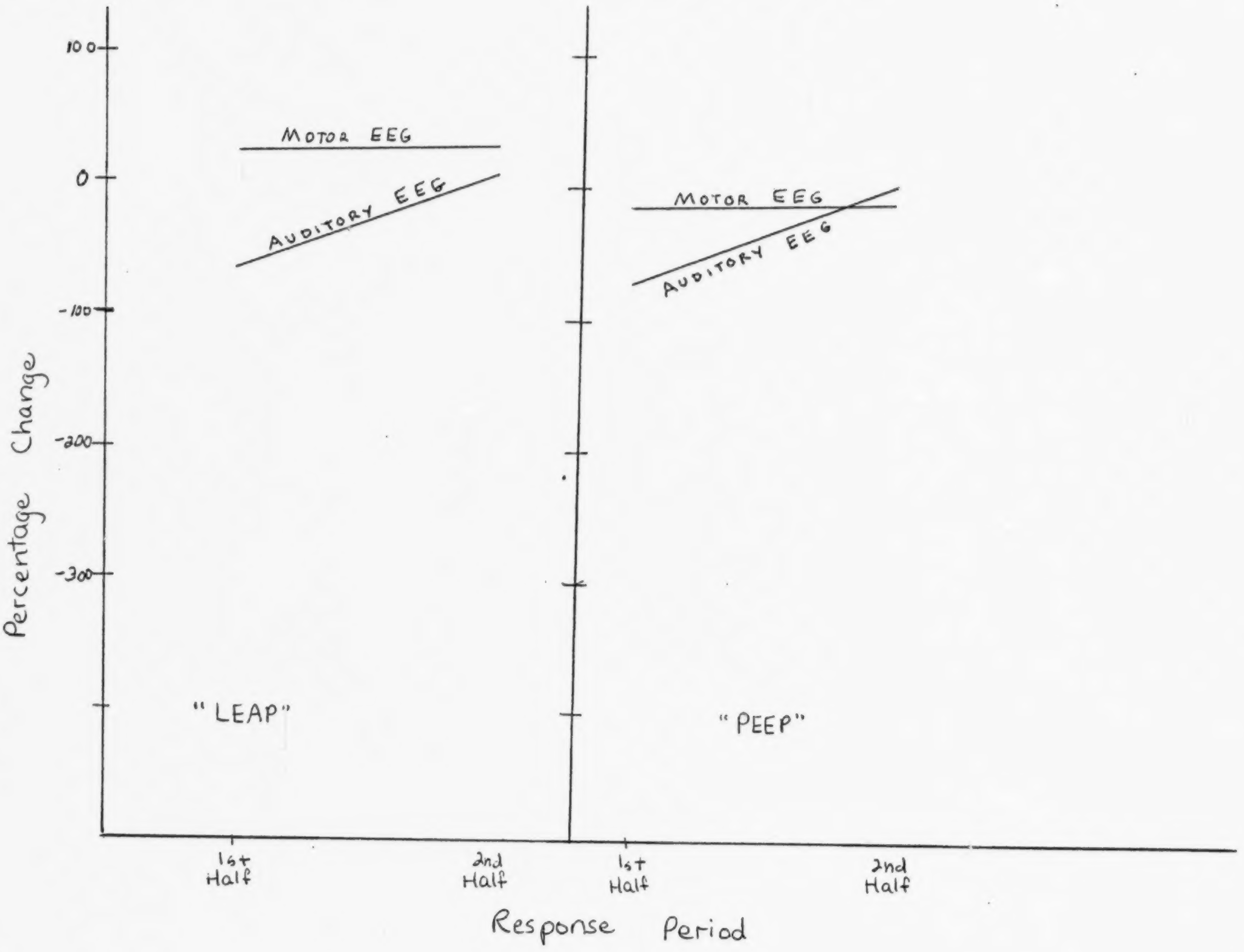

100
0
-100
-200
-300
Percentage Change
MOTOR EEG
AUDITORY EEG
"LEAP"
MOTOR EEG
AUDITORY EEG
"PEEP"
1st Half
2nd Half
1st Half
2nd Half
Response Period

Fig. 12. Percentage Change Over Rest of Confidence Limits of EEG Responses for Subject 2 During Repeat Aloud Condition

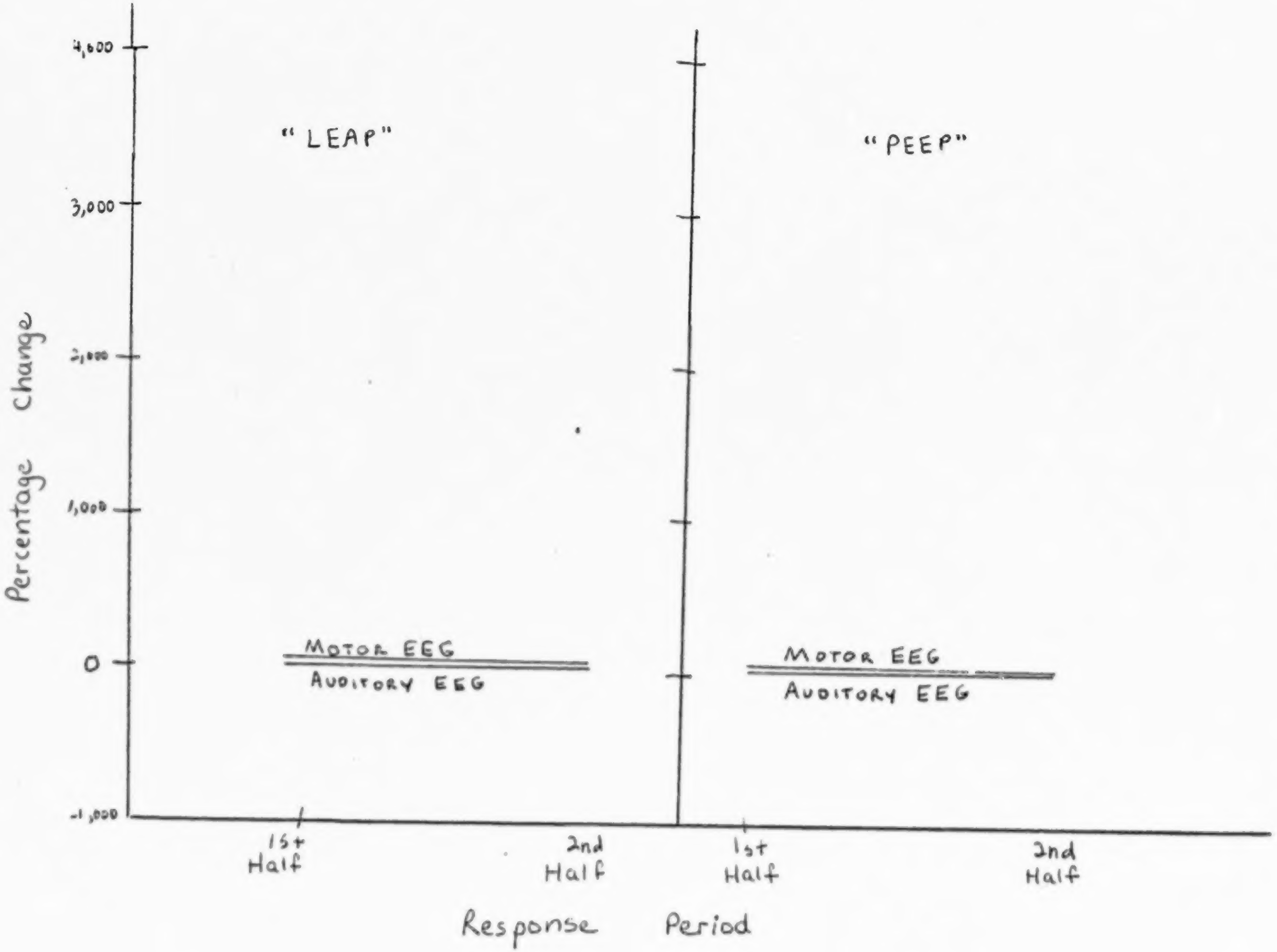

"LEAP"
"PEEP"
Percentage Change
4,000
3,000
2,000
1,000
0
-1,000
Motor EEG
Auditory EEG
Motor EEG
Auditory EEG
1st Half
2nd Half
1st Half
2nd Half
Response Period

Fig. 13. Percentage Change Over Rest of Averages of EMG Responses for Subject 1 During Listen Only Condition

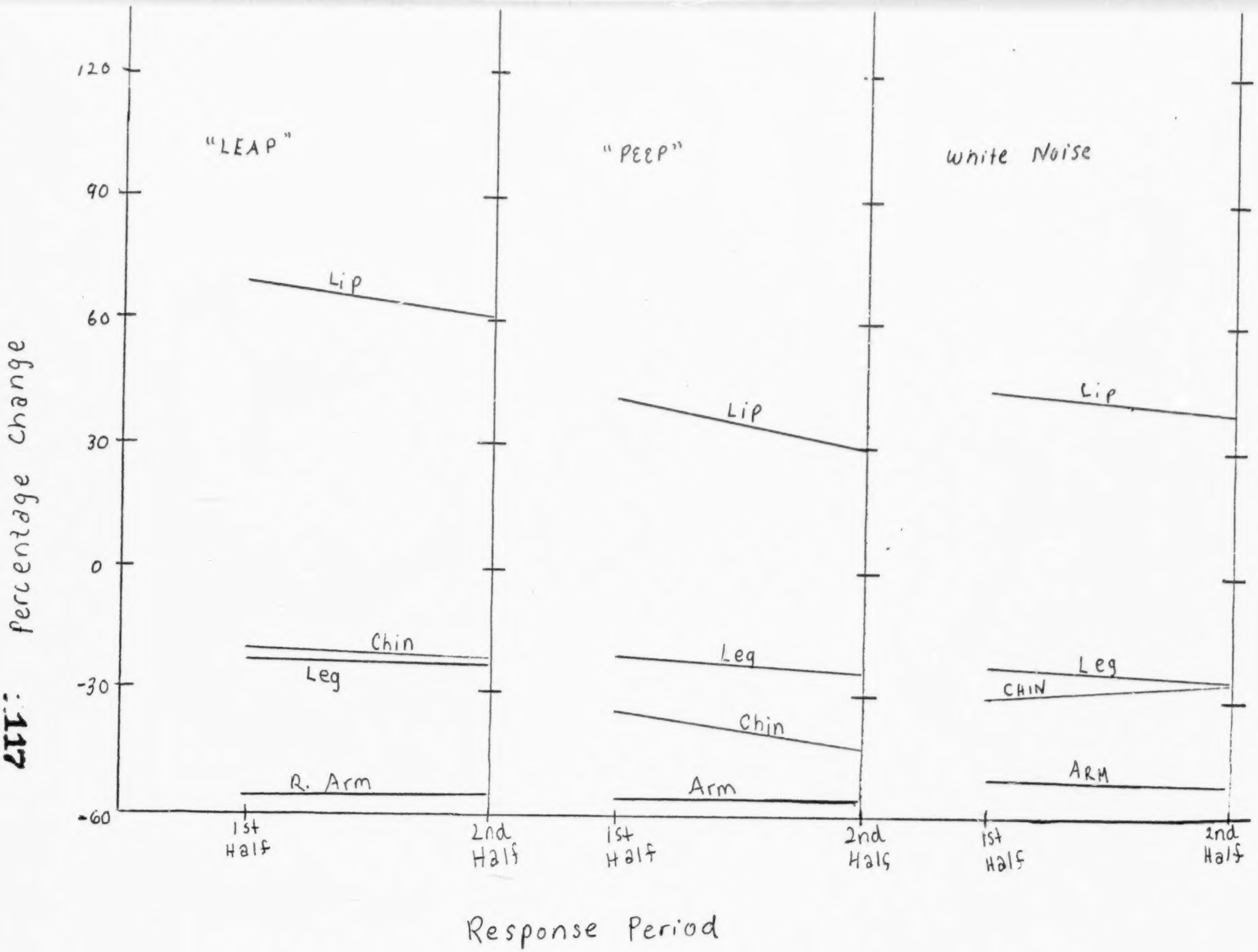

"LEAP"
"PEEP"
White Noise
Lip
Chin
Leg
R. Arm
Lip
Leg
Chin
Arm
Lip
Leg
CHIN
ARM
120
90
60
30
0
-30
-60
Percentage Change
1st Half
2nd Half
1st Half
2nd Half
1st Half
2nd Half
Response Period

Fig. 14. Percentage Change Over Rest of Averages of EMG Responses for Subject 1 During Listen-Repeat Condition

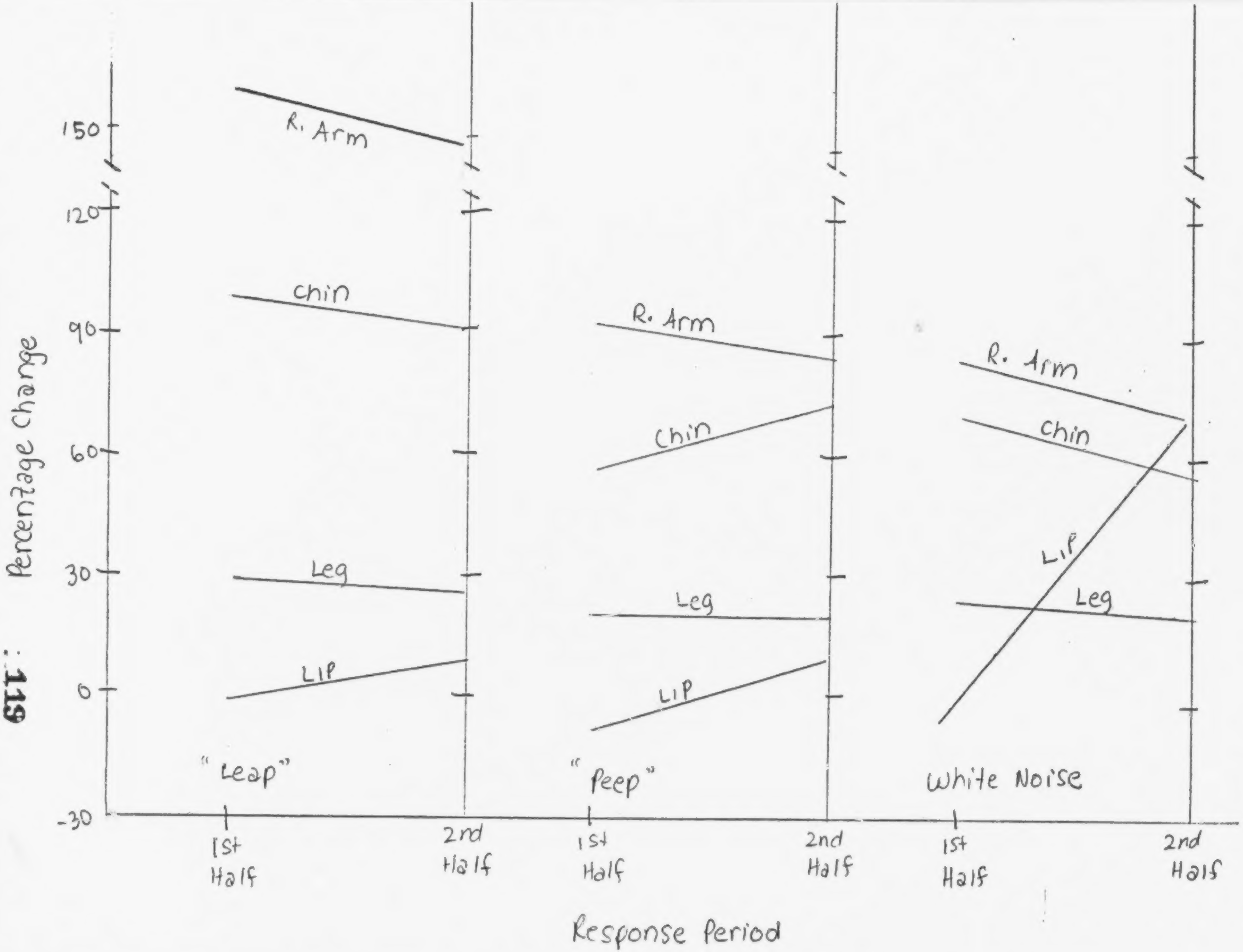

150
120
90
60
30
0
-30
Percentage Change
R. Arm
chin
Leg
LIP
"Leap"
1st Half
2nd Half
R. Arm
Chin
Leg
LIP
"Peep"
1st Half
2nd Half
R. Arm
Chin
LIP
Leg
White Noise
1st Half
2nd Half
Response Period

Fig. 15. Percentage Change Over Rest of Averages of EMG Responses for Subject 2 During Listen Only Condition

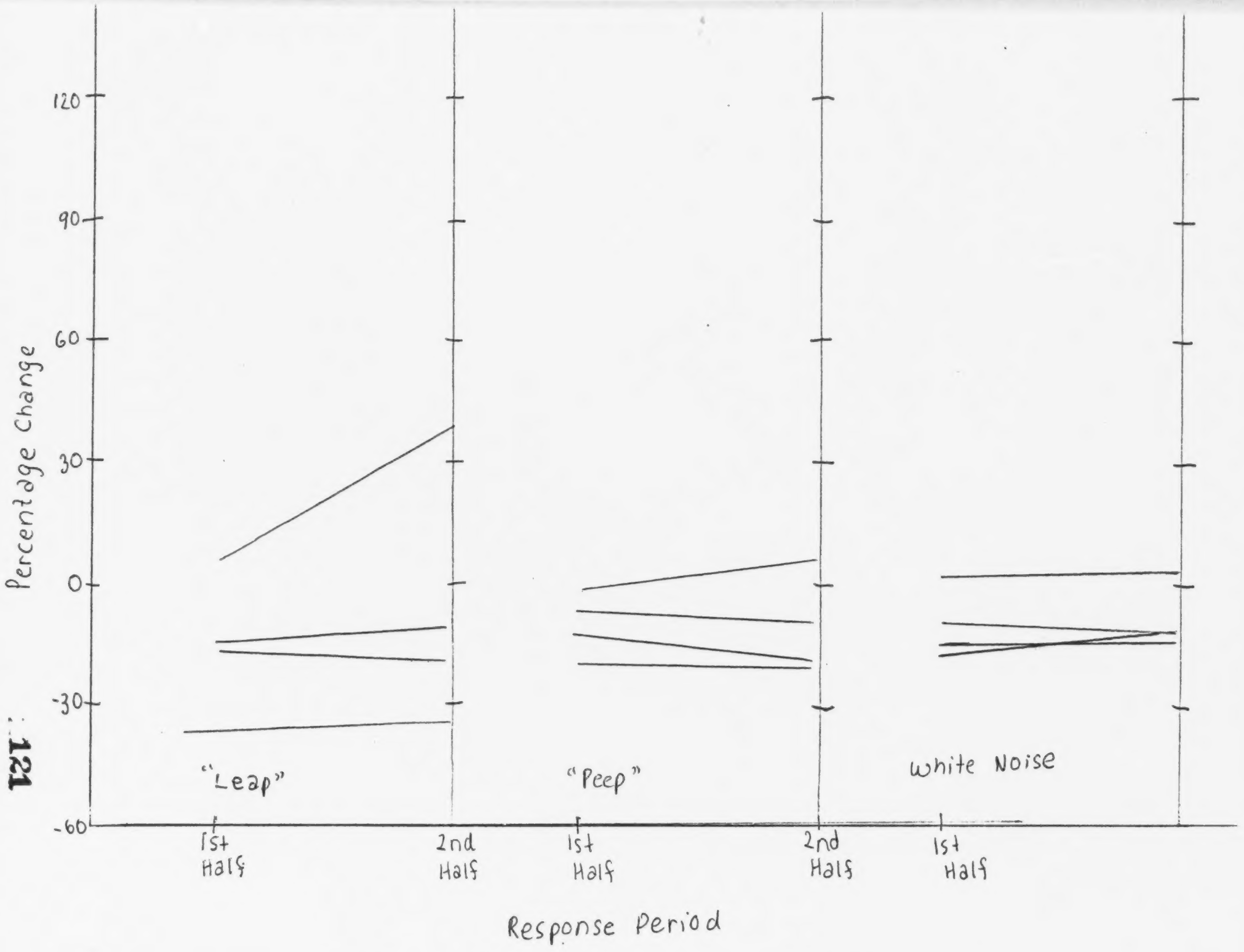
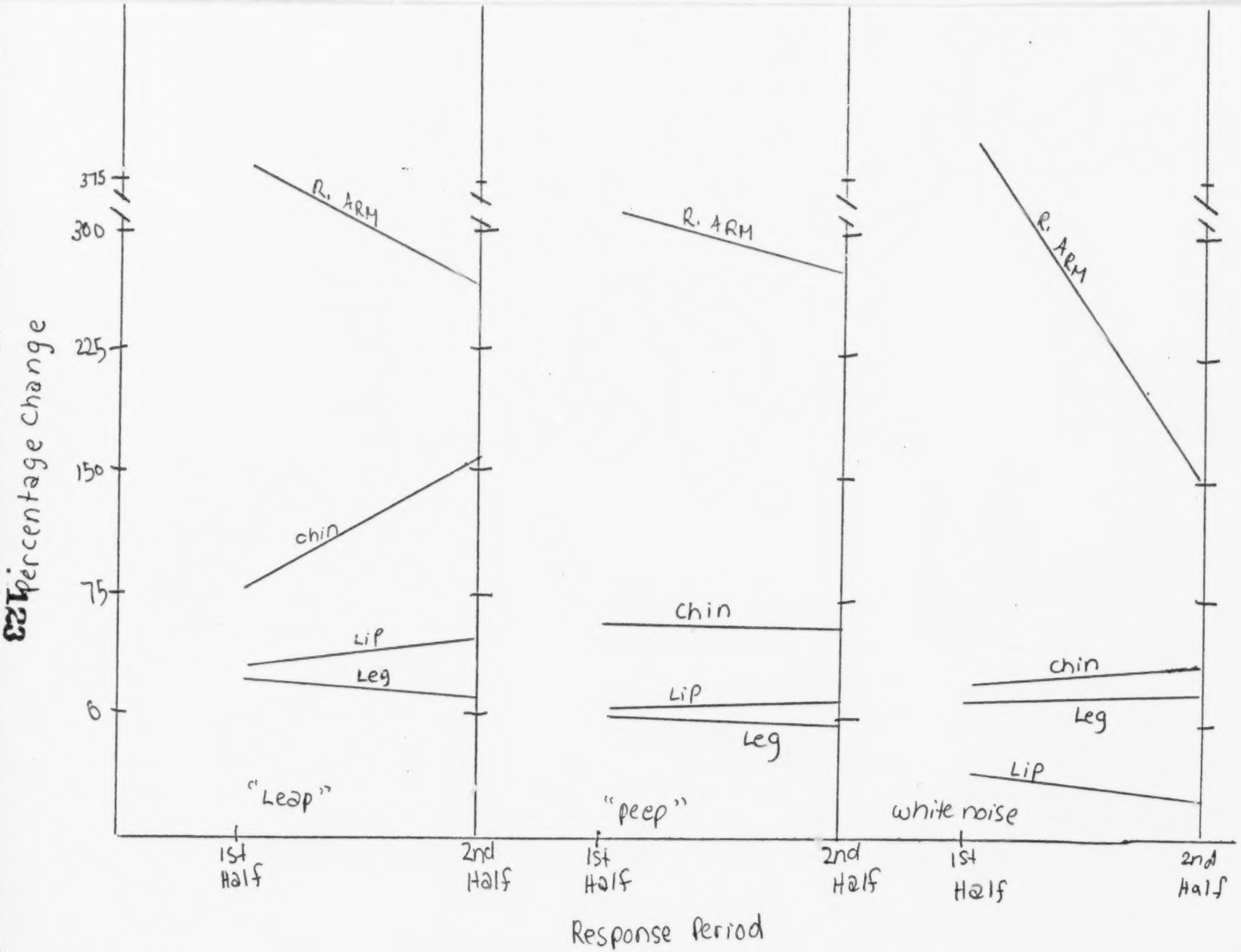

Percentage Change
120
90
60
30
0
-30
-60
"Leap"
"Peep"
White Noise
1st Half
2nd Half
1st Half
2nd Half
1st Half
Response Period

Fig. 16. Percentage Change Over Rest of Averages of EMG Responses for Subject 2 During Listen-Repeat Condition


Percentage Change
375
300
225
150
75
0
R. ARM
chin
Lip
Leg
"Leap"
R. ARM
Chin
Lip
Leg
"peep"
R. ARM
chin
Leg
Lip
white noise
1st Half
2nd Half
1st Half
2nd Half
1st Half
2nd Half
Response Period

the Listen-Repeat and Repeat conditions relative to rest was always greater than the increase shown by the control measure, the right leg.

It might seem, then, that the increases in perferred arm activity during the Listen-Repeat condition were something more than a mere generalized arousal; however, the results in the white noise control condition argue against a verbal interpretation of this activity increase, for preferred arm activity in response to non-verbal white noise was nearly as great and in some cases, greater than in response to the verbal stimuli "leap" and "peep." In fact, all the EMG responses for both subjects during the Listen Only and Listen-Repeat conditions showed highly similar activity increases for white noise and the verbal stimuli indicating no differential response to verbal stimuli.

The same similarity of response to verbal and non-verbal stimuli seen in the EMG responses is also true of the EEGs for both subjects (Figures 17 - 20).

For the confidence limits, the most striking result is the fact of greater variability for the preferred arm of both subjects during the Listen-Repeat versus the Listen Only condition (Figures 21 - 28). This bears out the finding mentioned earlier; namely, that greater variability is a concomitant of activity increases in EMG measures.

The confidence limits for the EMGs also bear out the negative finding with respect to any differential response to verbal as opposed to non-verbal auditory stimuli. The confidence limits for the EEGs show no discernible pattern, similarities, or continuities of response except a tendency for a decrease in variability relative to rest for the auditory EEG for subject 1 during the second half of each stimulus and an almost total lack of change in variability relative to rest for subject 2.

Fig. 17. Percentage Change Over Rest of Averages of EEG Responses for Subject 1 During Listen Only Condition

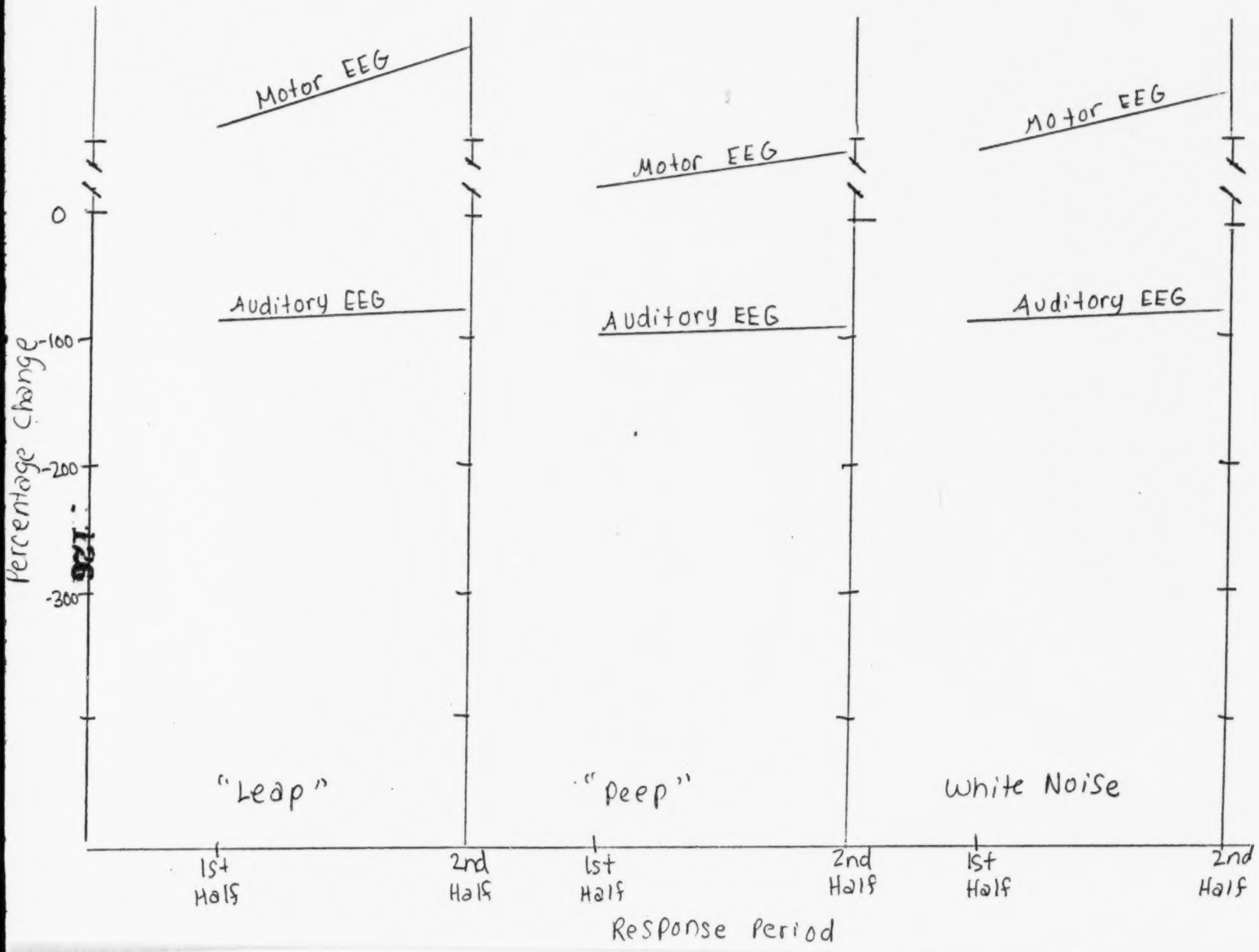

Percentage change
0
-100
-200
-300
Motor EEG
Auditory EEG
"Leap"
Motor EEG
Auditory EEG
"Peep"
Motor EEG
Auditory EEG
White Noise
1st Half
2nd Half
1st Half
2nd Half
1st Half
2nd Half
Response Period

Fig. 18. Percentage Change Over Rest of Averages of EEG Responses for Subject 1 During Listen-Repeat Condition

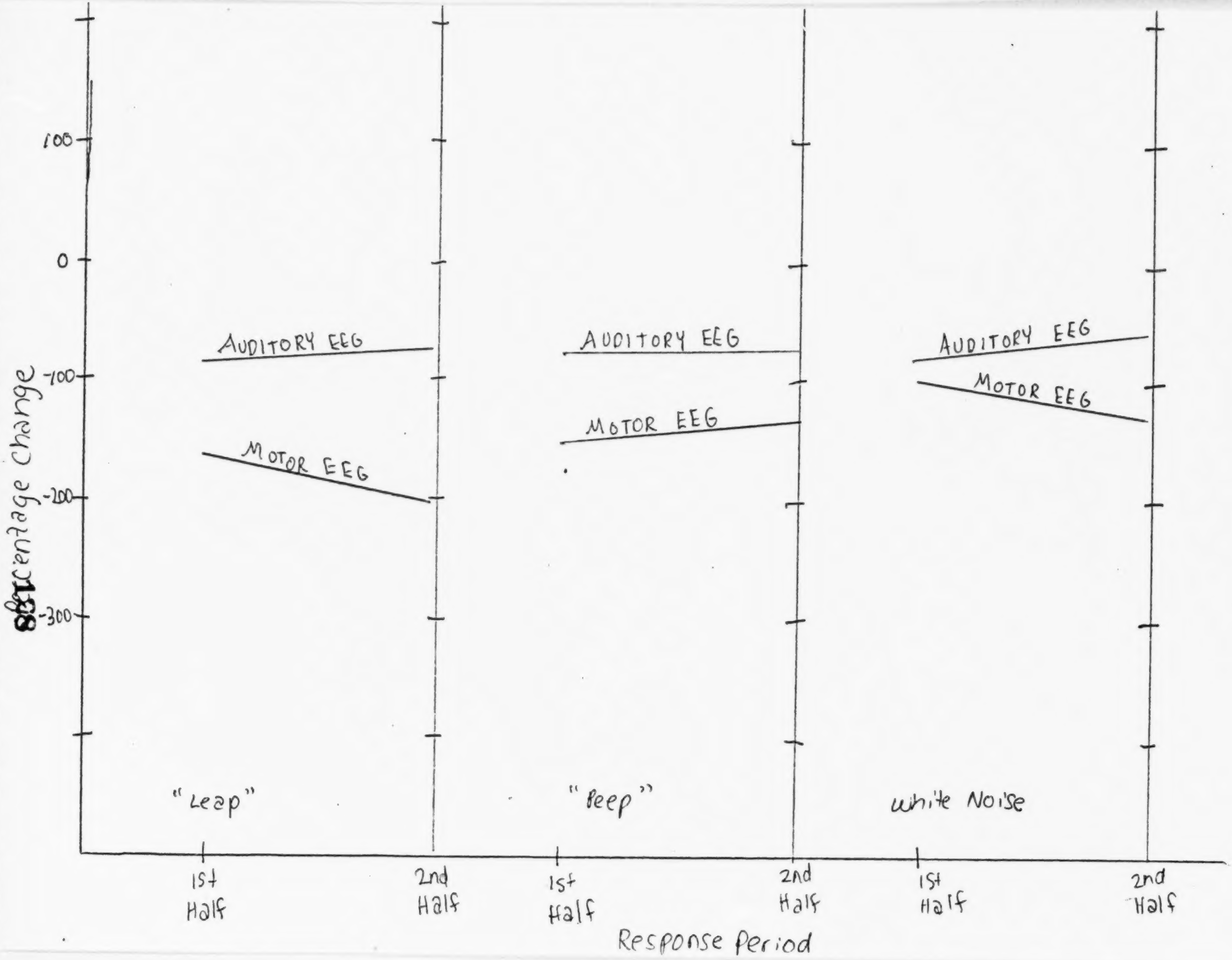

100
0
-100
-200
-300
Percentage Change
AUDITORY EEG
MOTOR EEG
"Leap"
AUDITORY EEG
MOTOR EEG
"Peep"
AUDITORY EEG
MOTOR EEG
White Noise
1st Half
2nd Half
1st Half
2nd Half
1st Half
2nd Half
Response Period

Fig. 19. Percentage Change Over Rest of Averages of EEG Responses for Subject 2 During Listen Only Condition

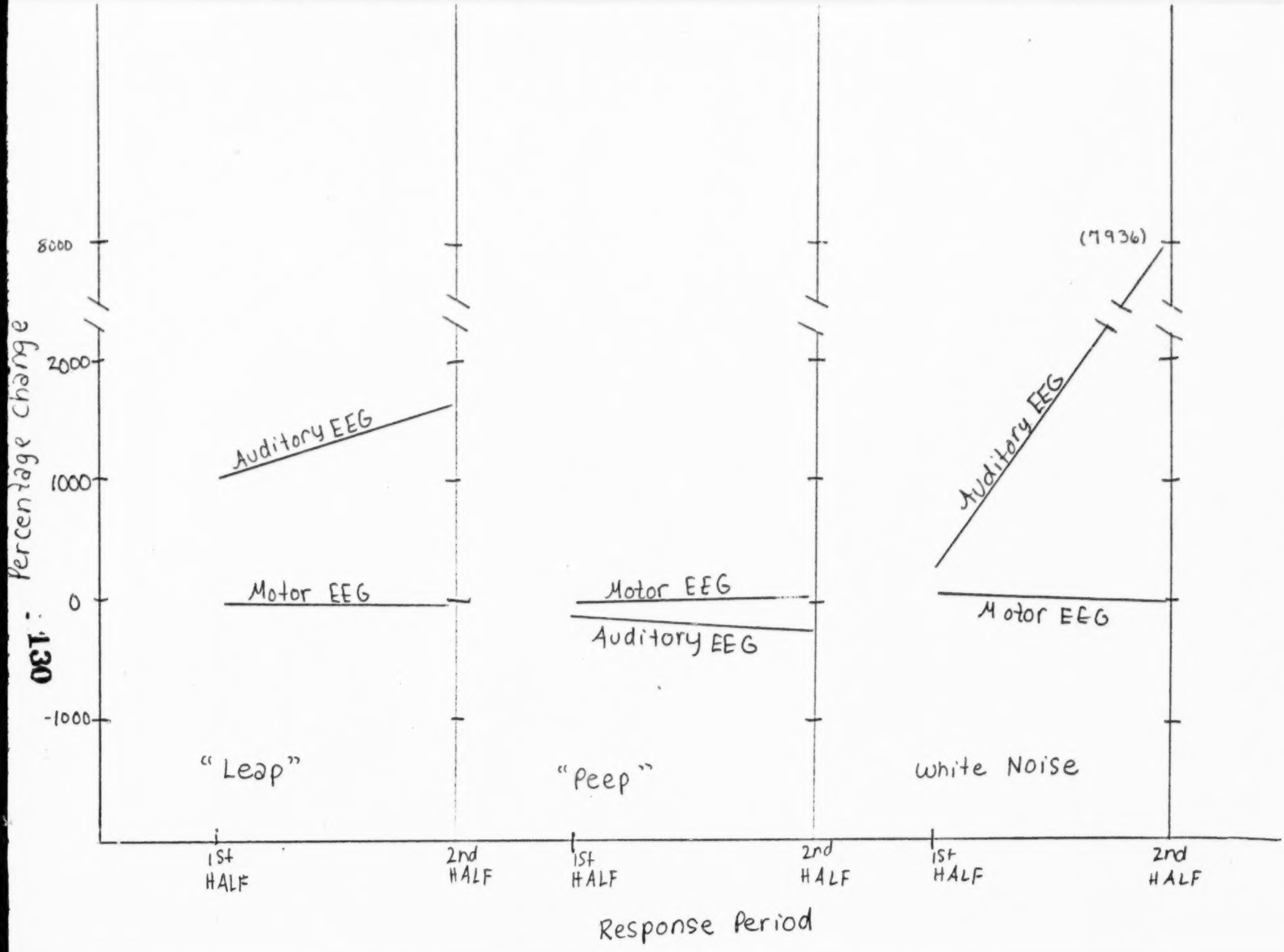

Percentage change
8000
2000
1000
0
-1000
(7936)
Auditory EEG
Motor EEG
Motor EEG
Auditory EEG
Auditory EEG
Motor EEG
"Leap"
"Peep"
White Noise
1st HALF
2nd HALF
1st HALF
2nd HALF
1st HALF
2nd HALF
Response Period

Fig. 20. Percentage Change Over Rest of Averages of EEG Responses for Subject 2 During Listen-Repeat Condition

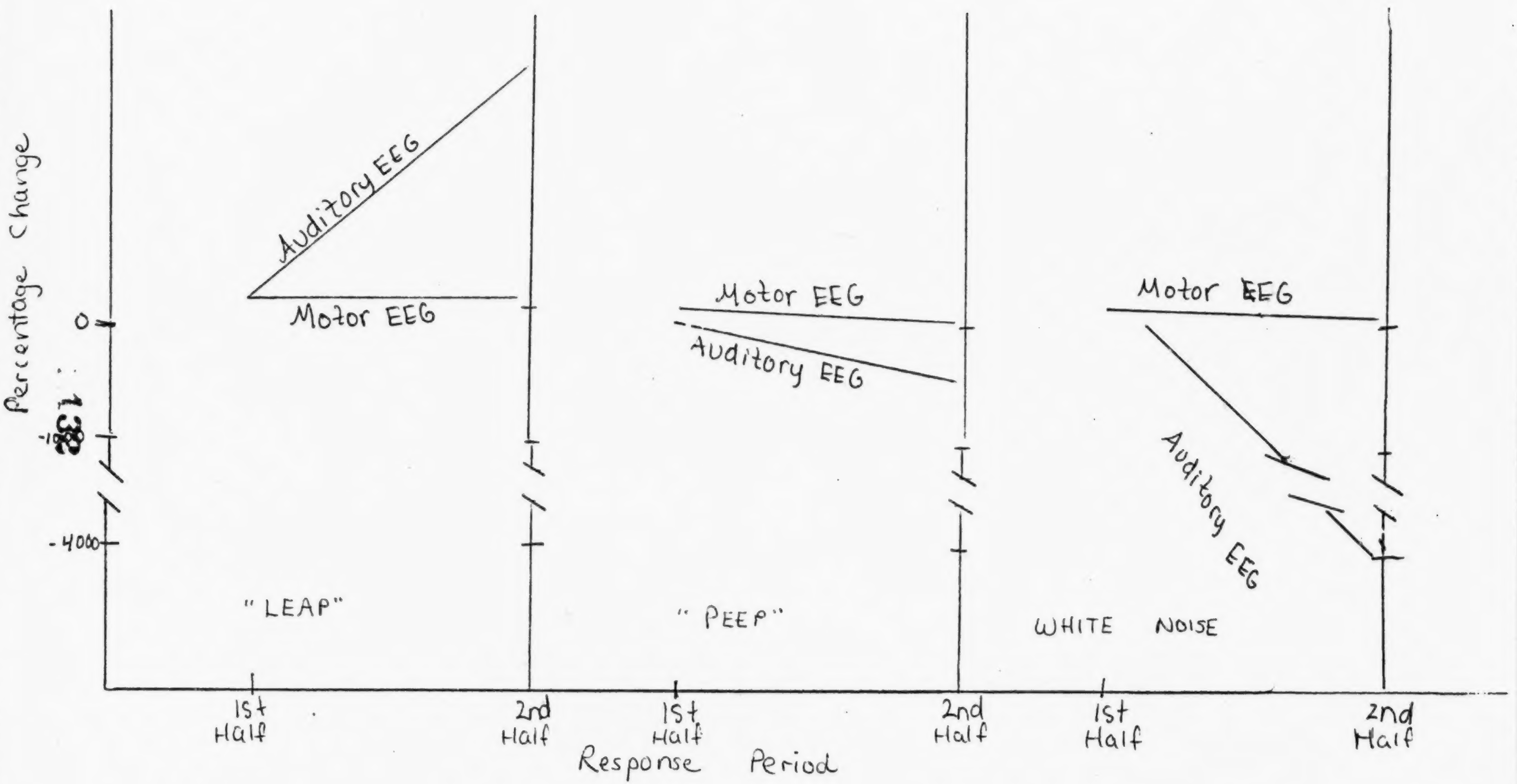
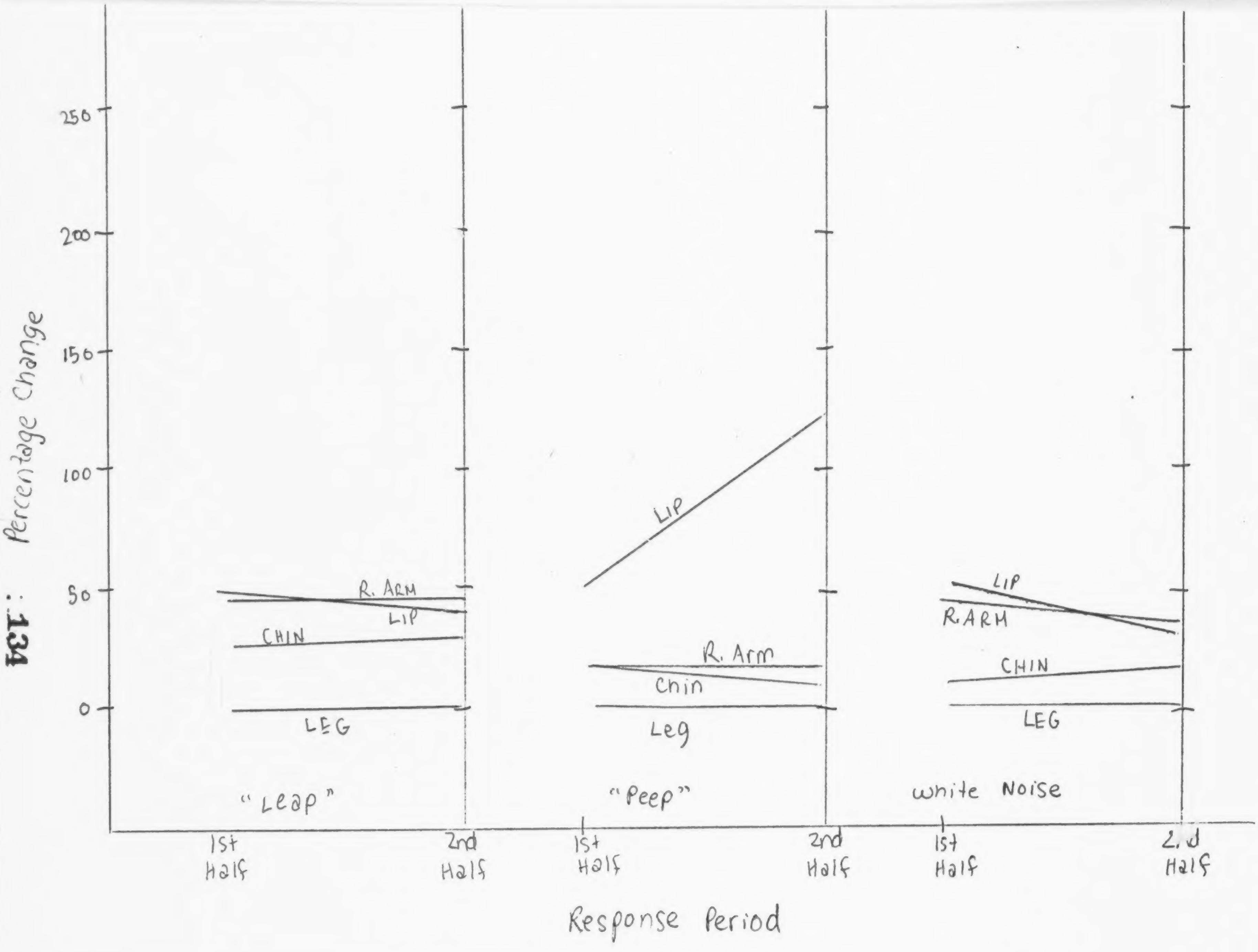

Percentage Change
0
-1
-4000
Auditory EEG
Motor EEG
"LEAP"
Motor EEG
Auditory EEG
"PEEP"
Motor EEG
Auditory EEG
WHITE NOISE
1st Half
2nd Half
1st Half
2nd Half
1st Half
2nd Half
Response Period

Fig. 21. Percentage Change Over Rest of Confidence Limits of EMG Responses for Subject 1 During Listen Only Condition



250
200
150
100
50
0
Percentage Change
"Leap"
R. ARM
LIP
CHIN
LEG
"Peep"
LIP
R. Arm
Chin
Leg
white Noise
LIP
R. ARM
CHIN
LEG
1st Half
2nd Half
1st Half
2nd Half
1st Half
2.d Half
Response Period

Fig. 22. Percentage Change Over Rest of Confidence Limits of EMG Responses for Subject 1 During Listen-Repeat Condition

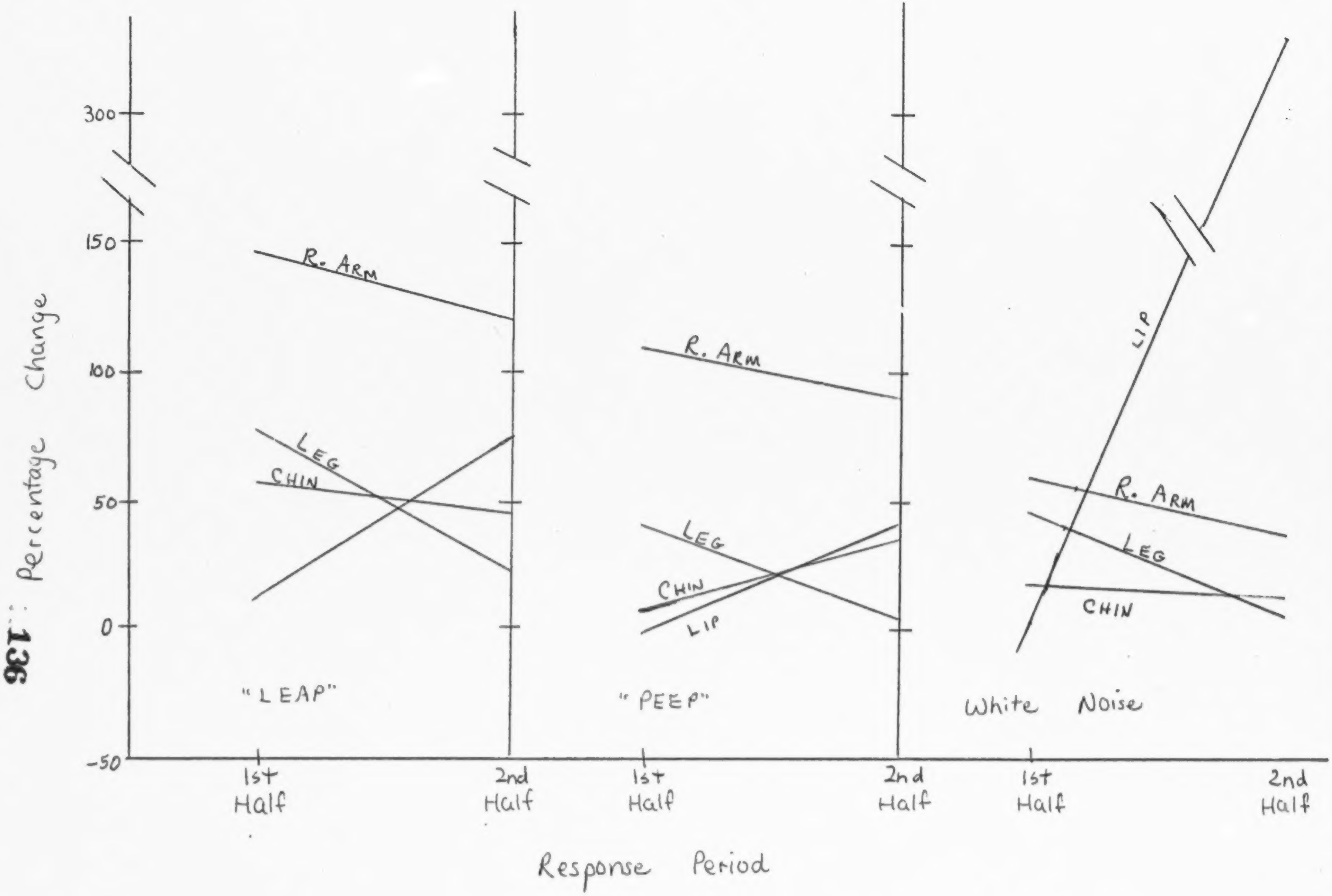

Percentage Change
300
150
100
50
0
-50
"LEAP"
"PEEP"
White Noise
R. ARM
LEG
CHIN
LIP
1st Half
2nd Half
Response Period

Fig. 23. Percentage Change Over Rest of Confidence Limits of EMG Responses for Subject 2 During Listen Only Condition

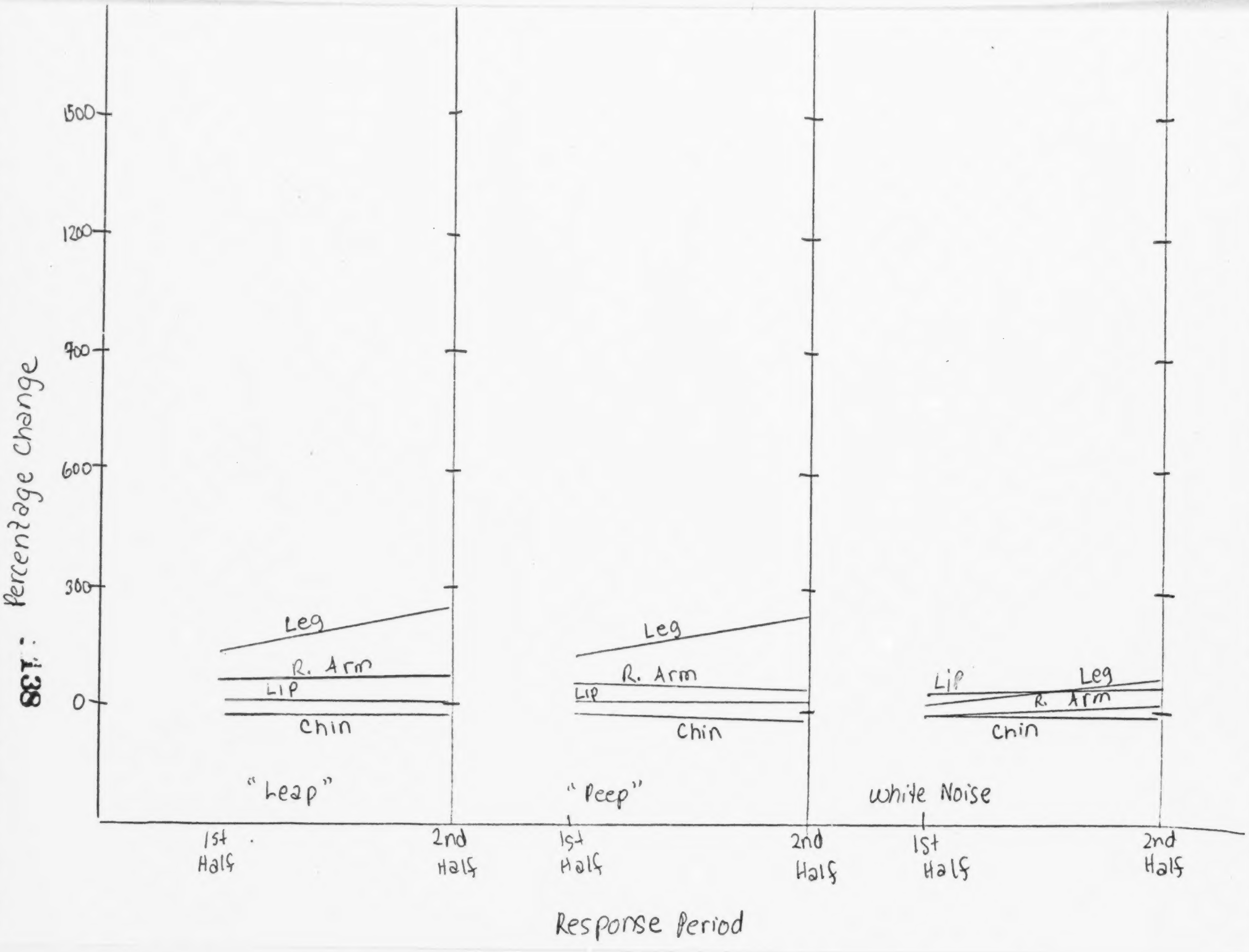

Percentage Change
1500
1200
900
600
300
0
Leg
R. Arm
Lip
Chin
"Leap"
Leg
R. Arm
Lip
Chin
"Peep"
Lip
Leg
R. Arm
Chin
White Noise
1st Half
2nd Half
1st Half
2nd Half
1st Half
2nd Half
Response Period

Fig. 24. Percentage Change Over Rest of Confidence Limits of EMG Responses for Subject 2 During Listen-Repeat Condition

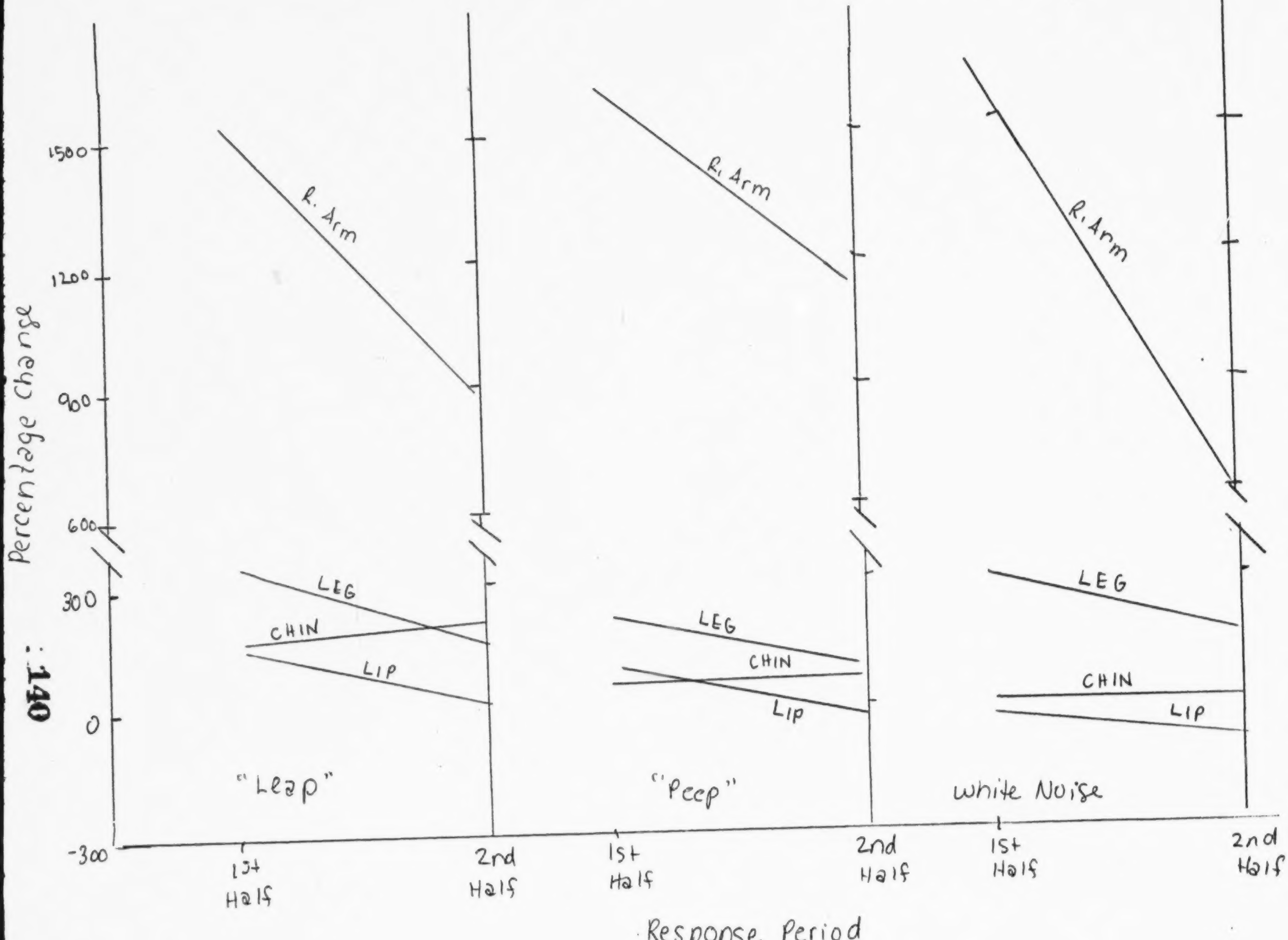

Percentage Change
1500
1200
900
600
300
0
-300
R. Arm
LEG
CHIN
LIP
"Leap"
R. Arm
LEG
CHIN
LIP
"Peep"
R. Arm
LEG
CHIN
LIP
White Noise
1st Half
2nd Half
1st Half
2nd Half
1st Half
2nd Half
Response Period

Fig. 25. Percentage Change Over Rest of Confidence Limits of EEG Responses for Subject 1 During Listen Only Condition

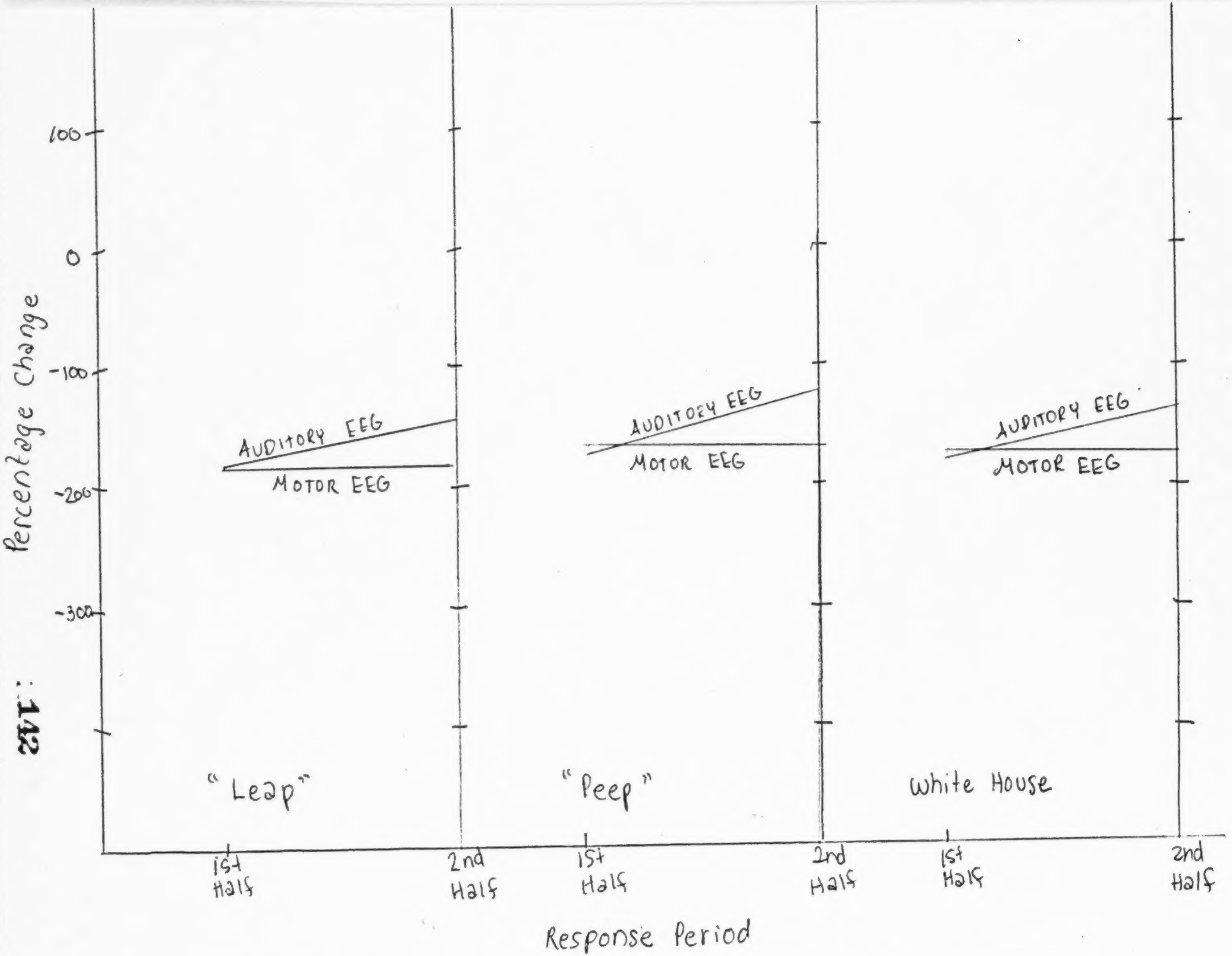
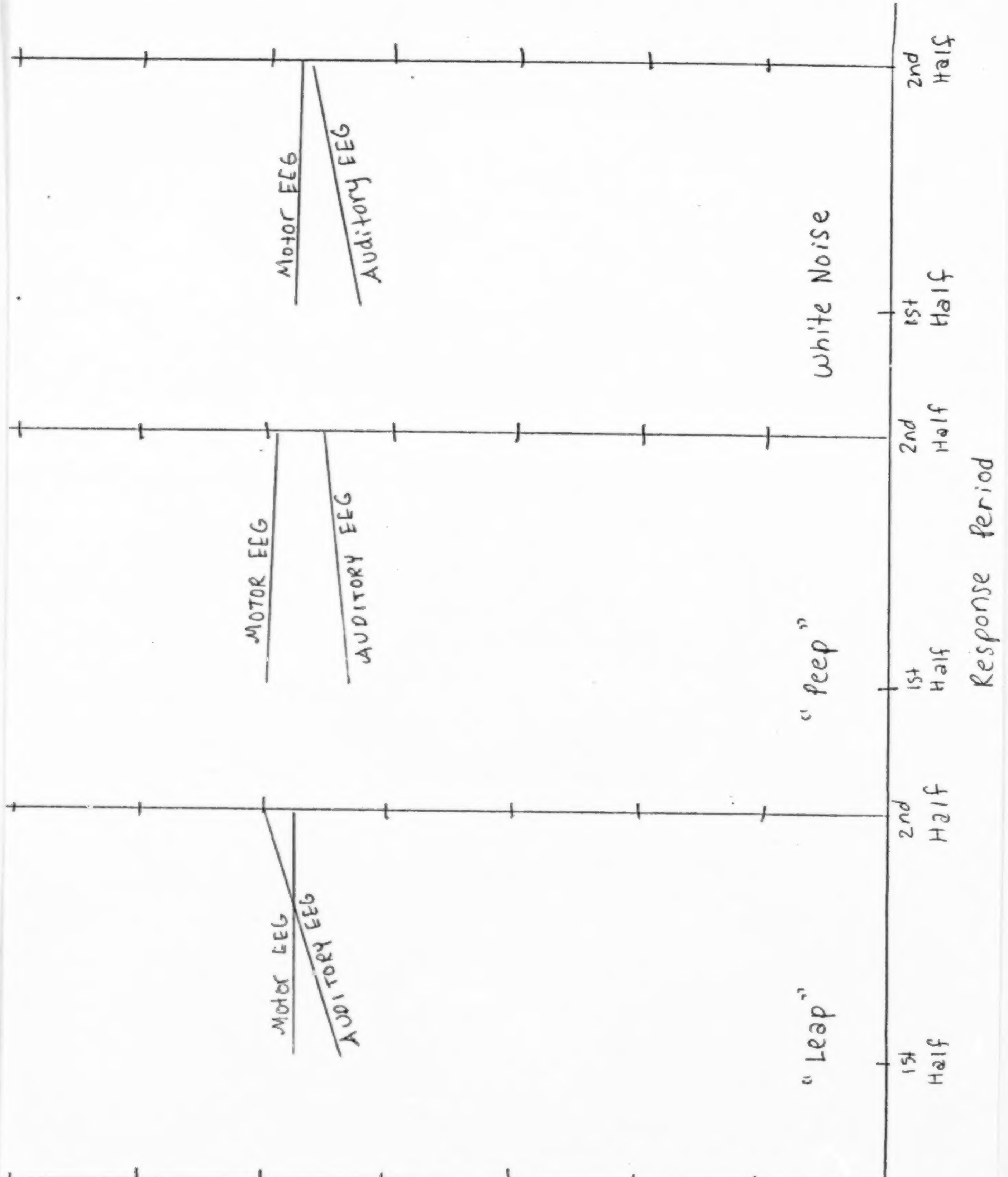

Percentage Change
100
0
-100
-200
-300
AUDITORY EEG
MOTOR EEG
"Leap"
AUDITORY EEG
MOTOR EEG
"Peep"
AUDITORY EEG
MOTOR EEG
White House
1st Half
2nd Half
1st Half
2nd Half
1st Half
2nd Half
Response Period

Fig. 26. Percentage Change Over Rest of Confidence Limits of EEG Responses for Subject 1 During Listen-Repeat Condition



"Leap"
Motor EEG
AUDITORY EEG
"Peep"
MOTOR EEG
AUDITORY EEG
White Noise
Motor EEG
Auditory EEG
100
0
-100
-200
-300
1st Half
2nd Half
1st Half
2nd Half
1st Half
2nd Half
Response Period

Fig. 27. Percentage Change Over Rest of Confidence Limits of EEG Responses for Subject 2 During Listen Only Condition

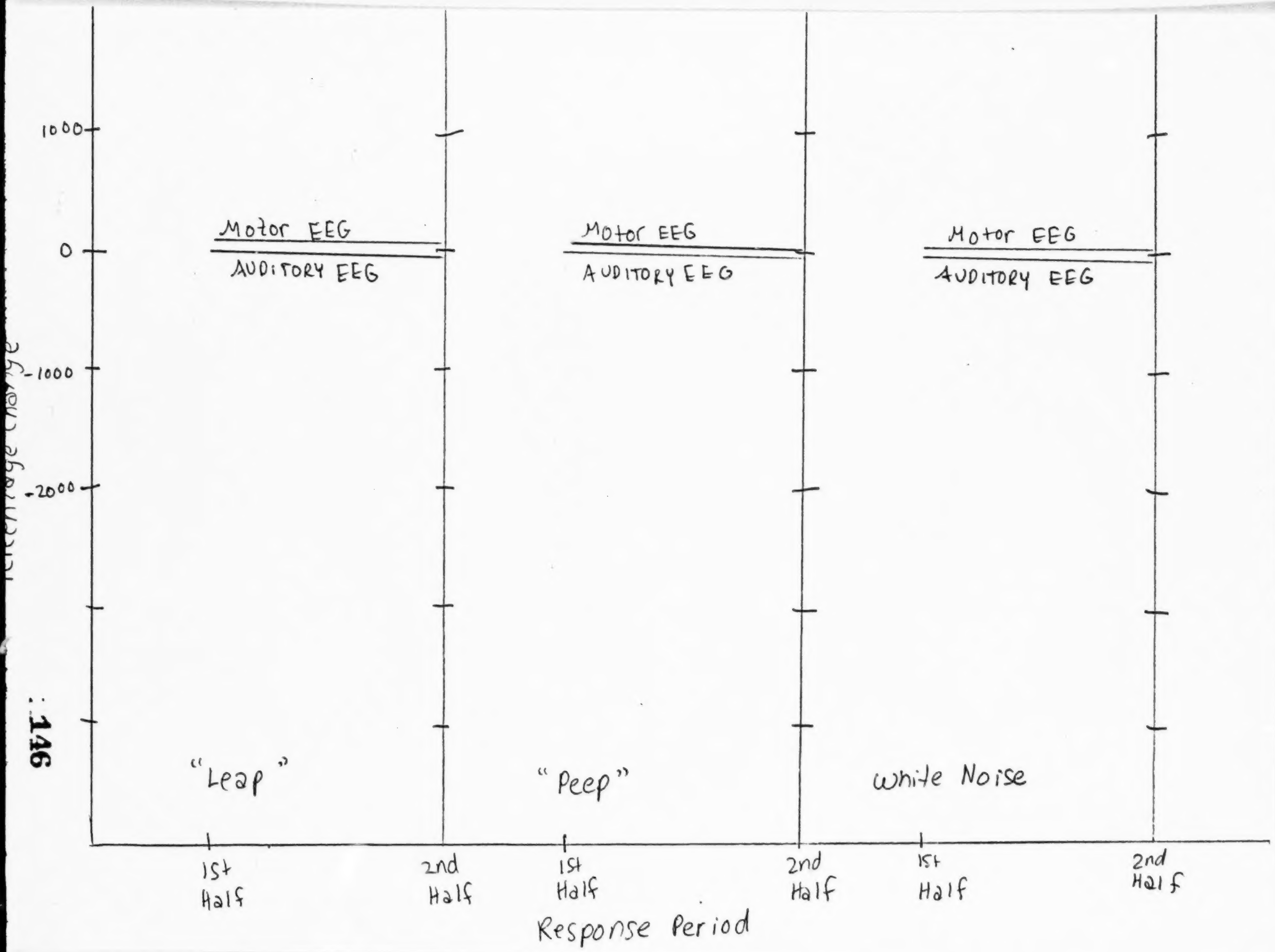
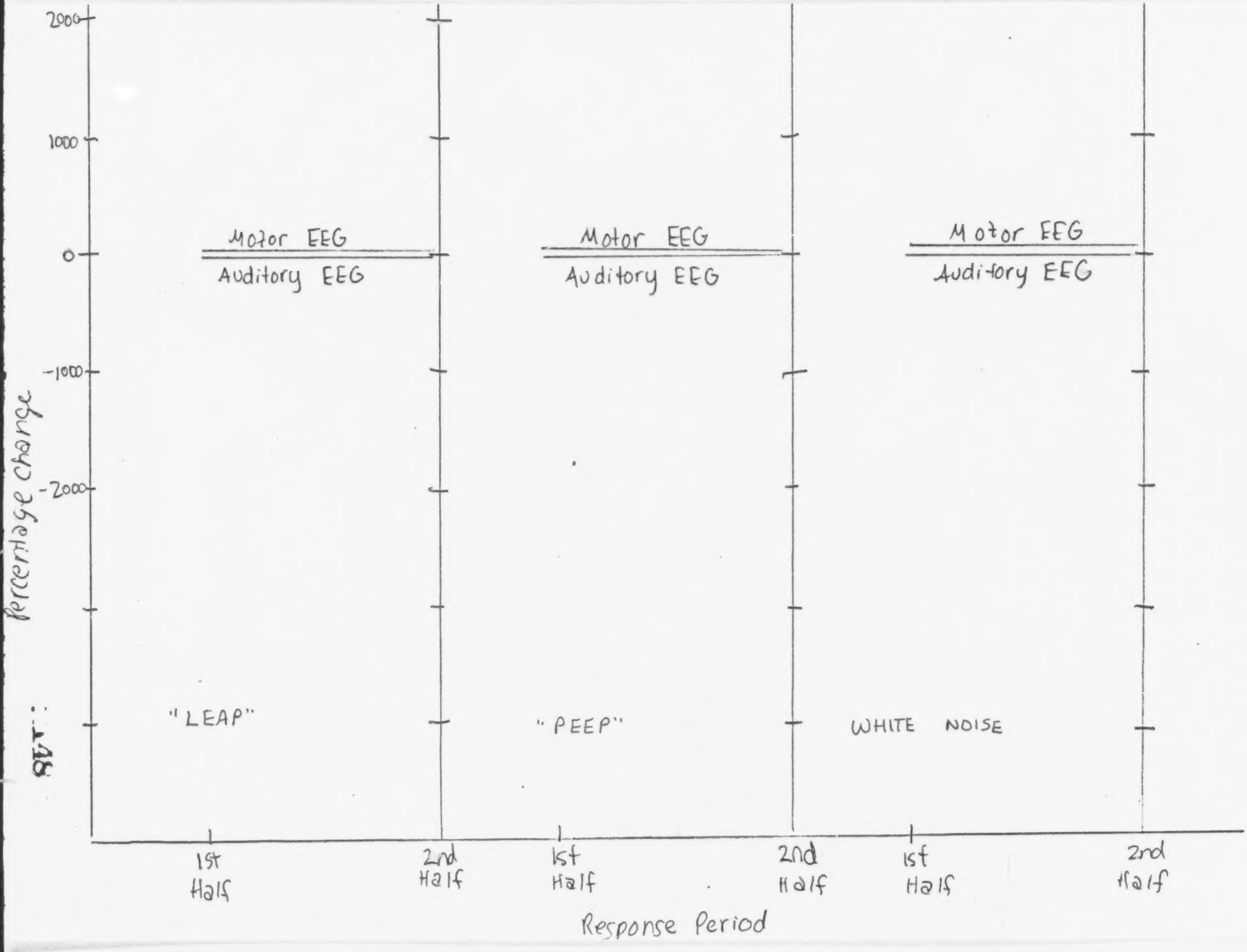

1000
0
-1000
-2000
ercentage change
Motor EEG
AUDITORY EEG
Motor EEG
AUDITORY EEG
Motor EEG
AUDITORY EEG
"Leap"
"Peep"
White Noise
1st Half
2nd Half
1st Half
2nd Half
1st Half
2nd Half
Response Period

Fig. 28. Percentage Change Over Rest of Confidence LImits of EEG Responses for Subject 2 During Listen-Repeat Conditions


2000
1000
0
-1000
-2000
Percentage change
Motor EEG
Auditory EEG
Motor EEG
Auditory EEG
Motor EEG
Auditory EEG
"LEAP"
"PEEP"
WHITE NOISE
1st Half
2nd Half
1st Half
2nd Half
1st Half
2nd Half
Response Period

In summary, it might be well to evaluate the results of this study in terms of the three questions posed at the beginning of the study:

(1) Are there increases in covert oral activity as a concomitant of "mental" activity or thinking in a human subject? This study did find an increase in activity relative to rest in some oral measures during certain non-overt activity periods; i.e., listening to auditory stimuli; however, the site of these activity increases (chin or lip) varied from subject to subject and from condition to condition. Furthermore, the activity increases in the oral measures were in nine cases smaller than the increases seen in the presumably non-thinking-related control measure, the right leg. The preferred arm, which has been observed to be active during language processing activity (McGuigan & Bailey, 1969) showed the largest and most consistent activity increases relative to its resting baseline and relative to the control measure of all the responses monitored.

(2) Are covert oral activity increases during "thinking" actually language-related? and

(3) Is there any detectable invariance in EMG or EEG activity for repeated pronunciations of the same word and can this same variance be detected as one listens to that same word? It has already been shown (Figures 3, 4, 5, and 6) that the lip shows distinct activity patterns during the overt pronunciation of words such as "leap" and "peep" and further, that the pattern of activity can differentiate the word being pronounced. On the other hand, lip activity during the hearing of these same words shows no distinct pattern by which one can distinguish the stimulus being presented. This was particularly true during the Listen Only condition. In the Listen-Repeat condition, there was somewhat more distinctiveness of lip activity according to whether a labial or non-labial stimulus was being presented; but examination of the curves showed that much of this activity was antici-

patory of the actual pronunciation of the word. The chin showed equal non-distinctiveness of activity relative to the stimulus being heard (Figures 29 - 36). Therefore, we failed to verify Locke and Fehr's (1969) finding of more lip activity during processing of a labial versus a non-labial stimulus. It should be noted, however, that in the present study the subjects were merely listening to verbal stimuli whereas Locke and Fehr's subjects were involved in a learning-rehearsal task.

Further, as already noted, we found no more oral activity during the processing of verbal stimuli than during the hearing of non-verbal white noise. This could indicate that such increases in activity in the oral measures as were found during the verbal conditions were not language-related; however, such a conclusion fails to explain why the oral EMG responses were generally higher than the response in the leg during the white noise as well as during the verbal conditions when we might well expect to see similar levels of activity in all measures in response to the non-verbal white noise. One possible explanation for this phenomenon is that covert oral responses function during the processing of all auditory stimuli, hence, either no differences should be expected, or our instruments were not sufficiently sensitive to detect any distinctiveness of response to verbal as opposed to non-verbal auditory stimuli.

Fig. 29. Average and 95% Confidence Limits of Lip EMG for Subject 1 for "Leap" During Listen Only Condition

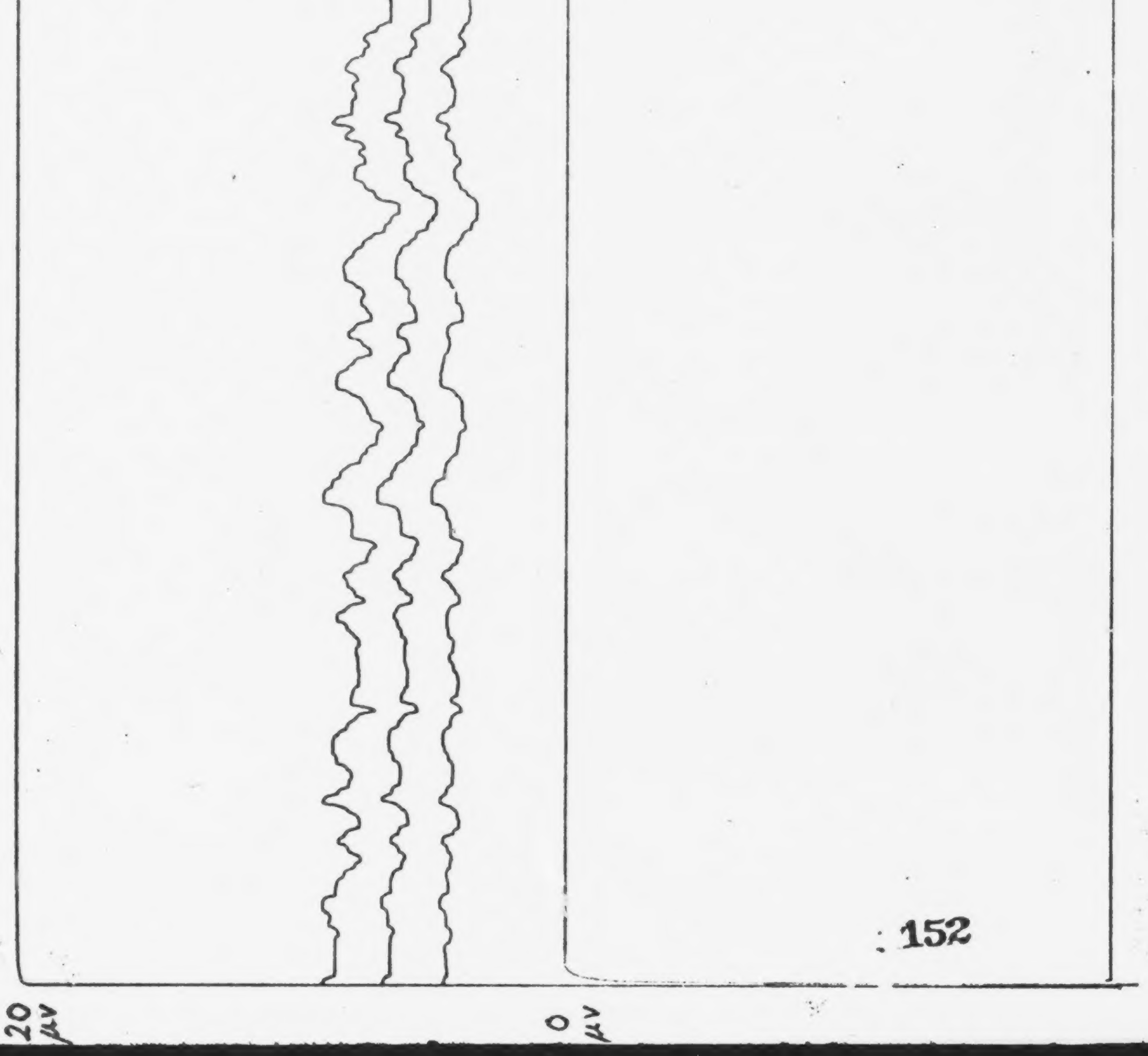

20 µV
0 µV
600 ms

Fig. 30. Average and 95% Confidence Limits of Lip EMG for Subject 1 for "Peep" During Listen Only Condition

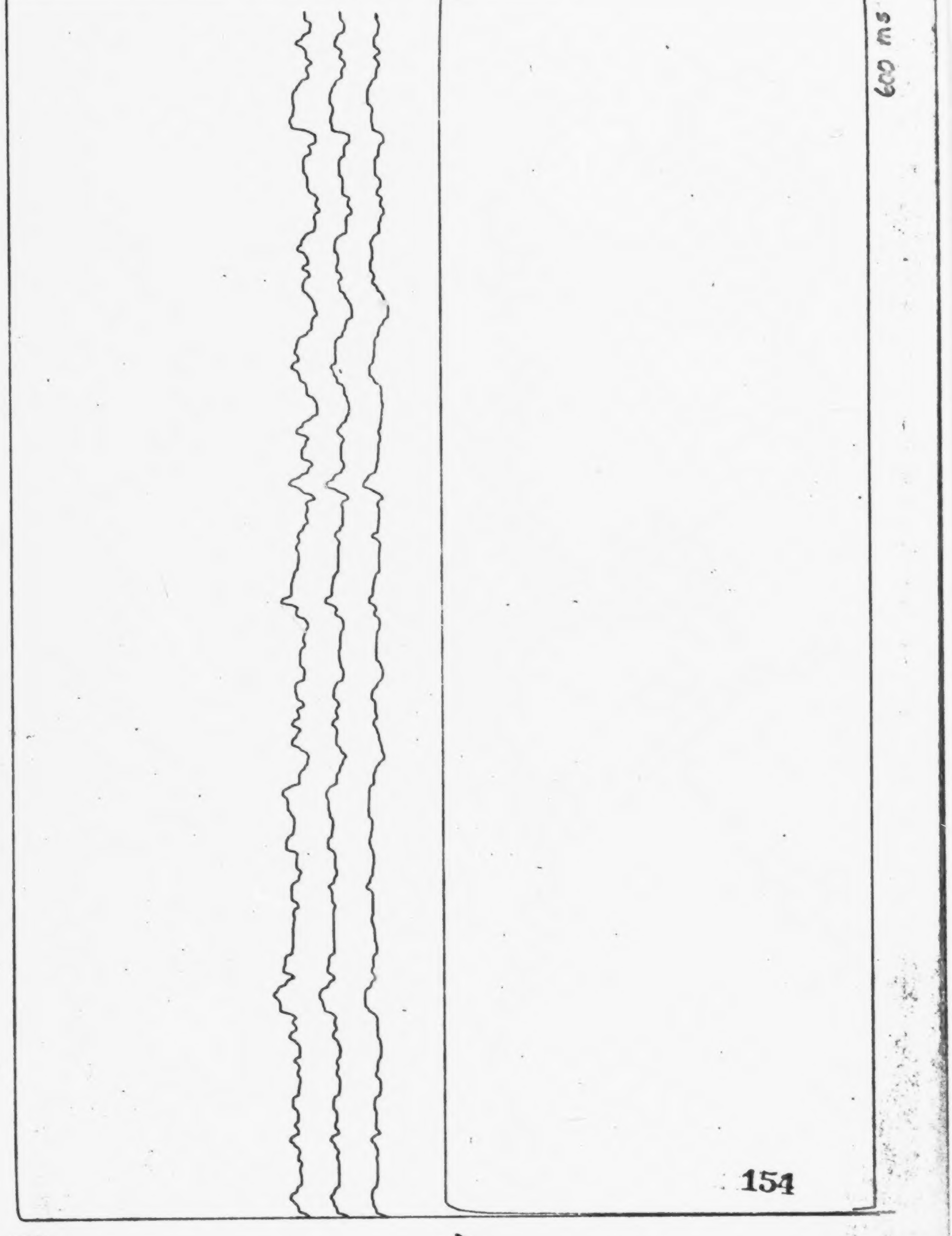

0 µV
0 µV
600 ms

Fig. 31. Average and 95% Confidence Limits of Lip EMG for Subject 1 for "Leap" During Listen-Repeat Condition (Expanded by factor of 8)

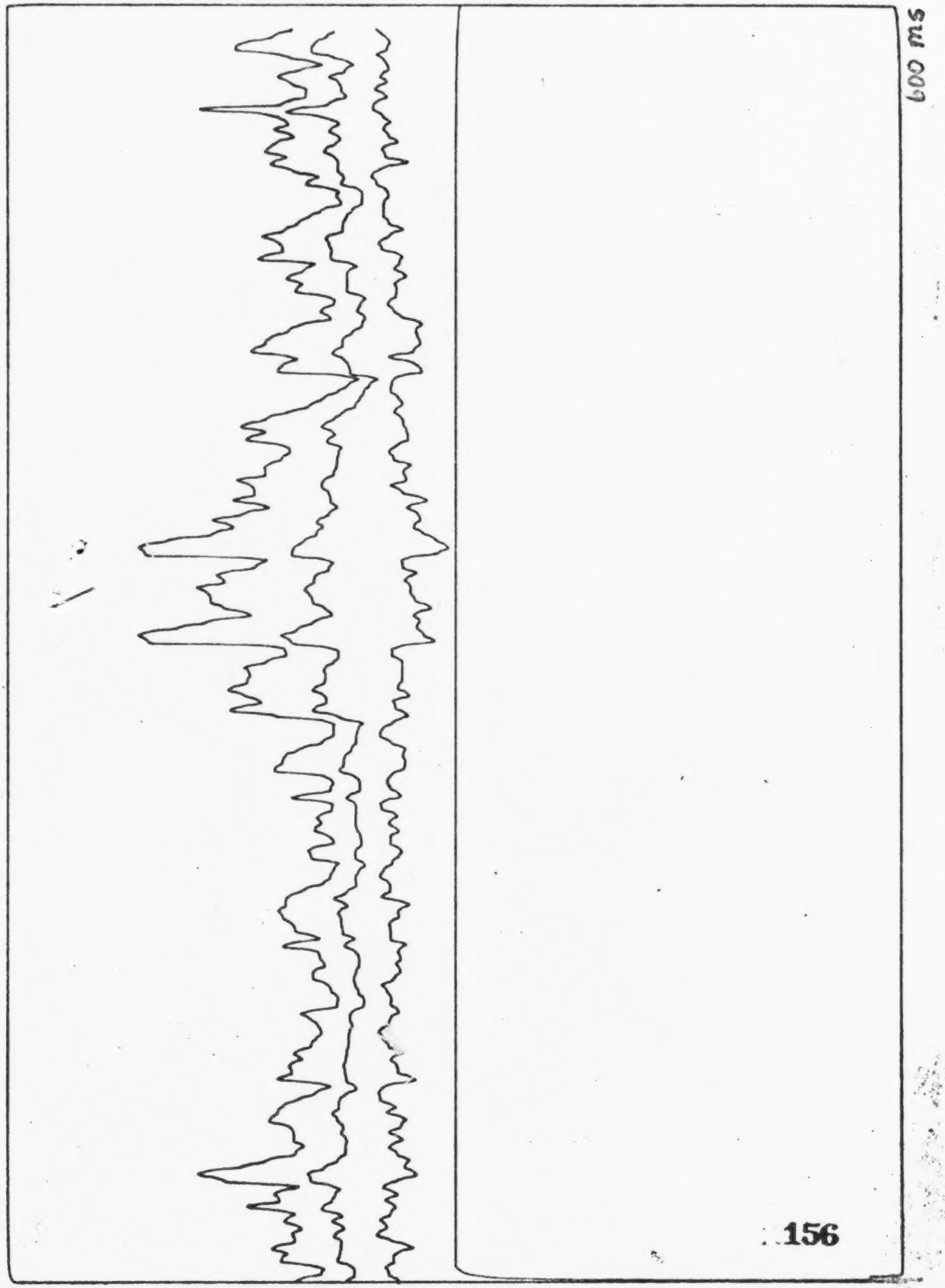

600 ms

Fig. 32. Average and 95% Confidence Limits of Lip EMG for Subject 1 for "Peep" During Listen-Repeat Condition (Expanded by factor of 4)

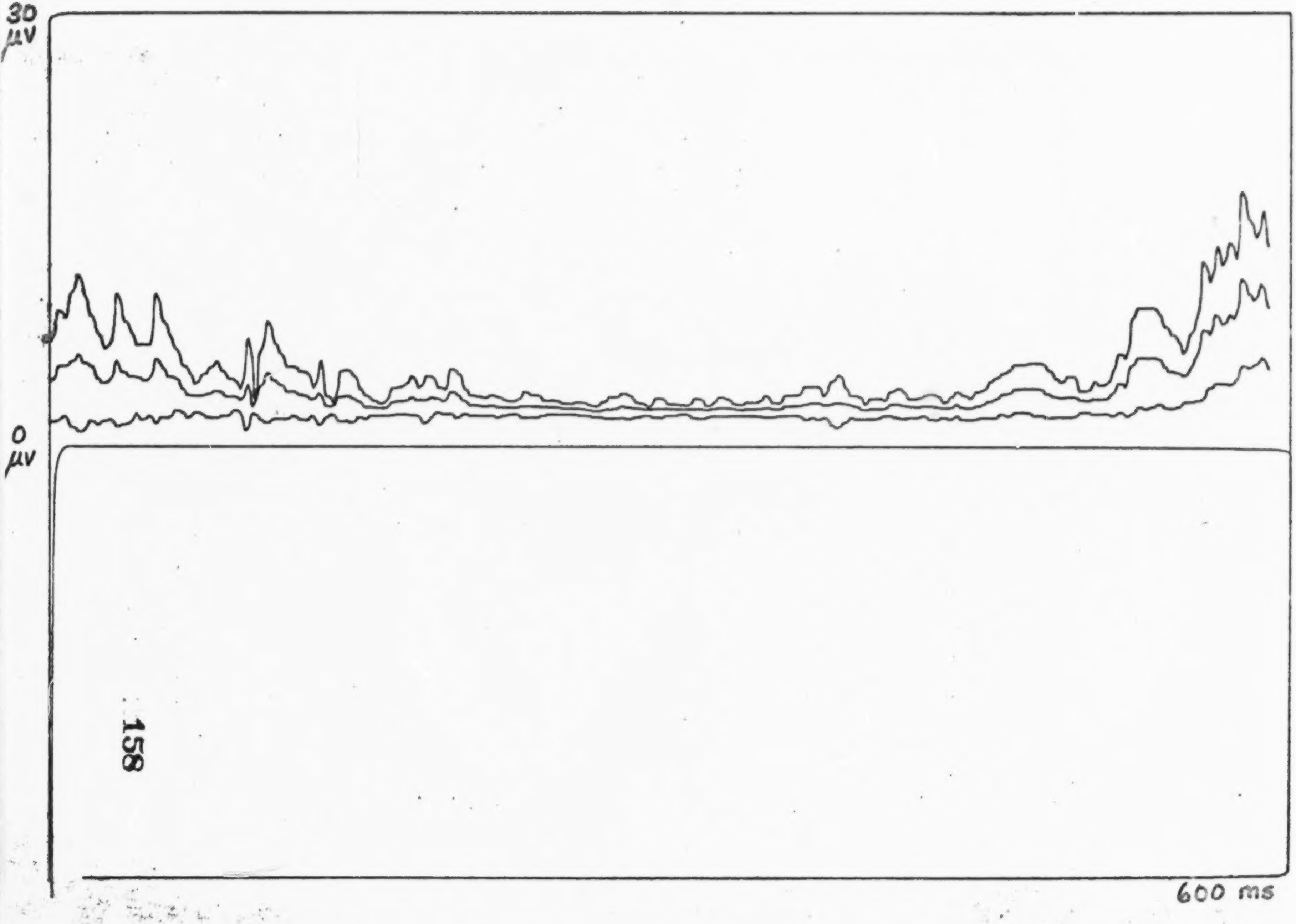

30 µV
0 µV
600 ms

Fig. 33. Average and 95% Confidence Limits of Lip EMG for Subject 2 for "Leap" During Listen Only Condition

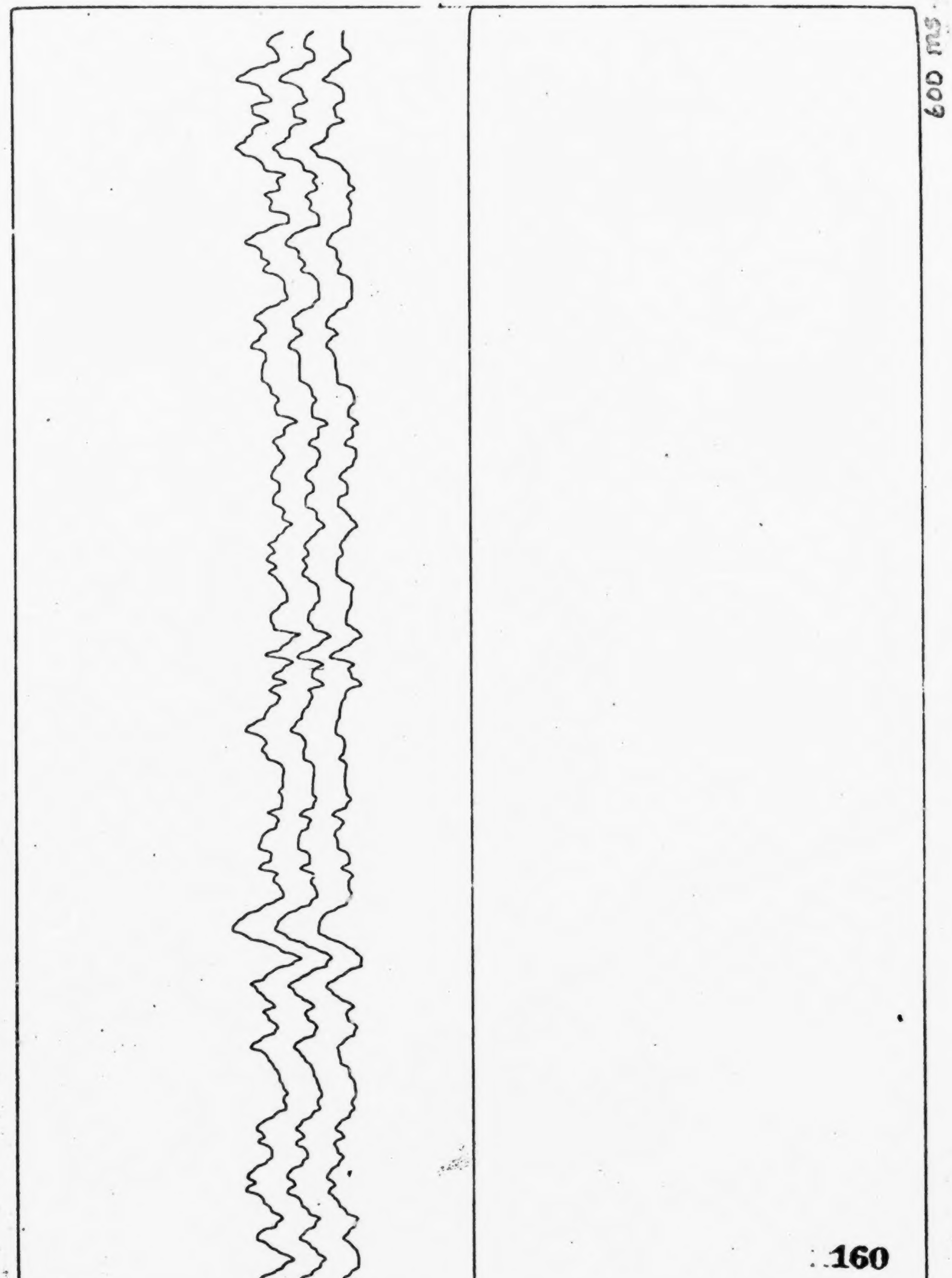

20 μV
0 μV
600 ms

Fig. 34. Average and 95% Confidence Limits of Lip EMG for Subject 2 for "Leap" During Listen-Repeat Condition (Expanded by factor of 4)

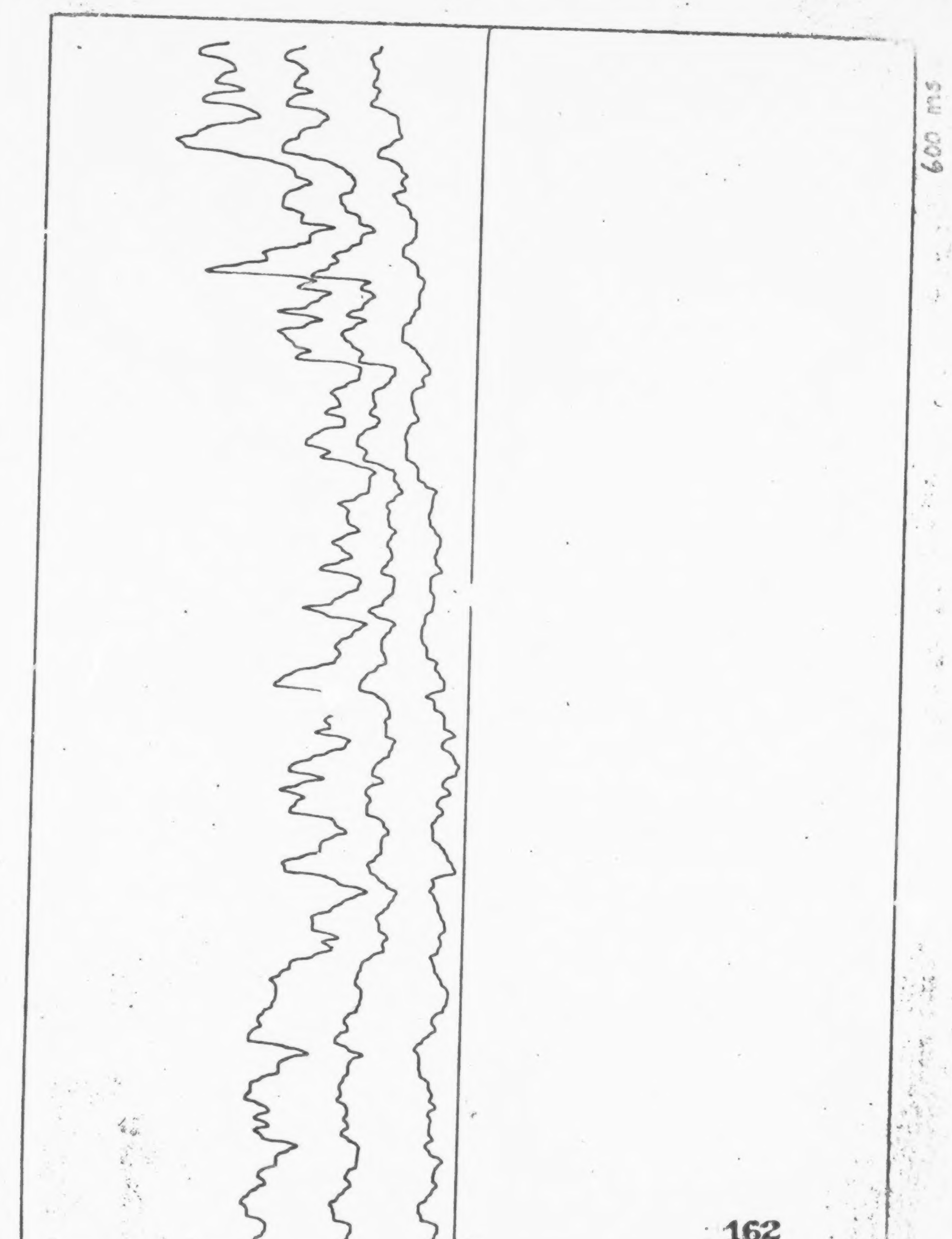

30 µV
0 µV
600 ms

Fig. 35. Average and 95% Confidence Limits of Lip EMG for Subject 2 for "Peep" During Listen Only Condition

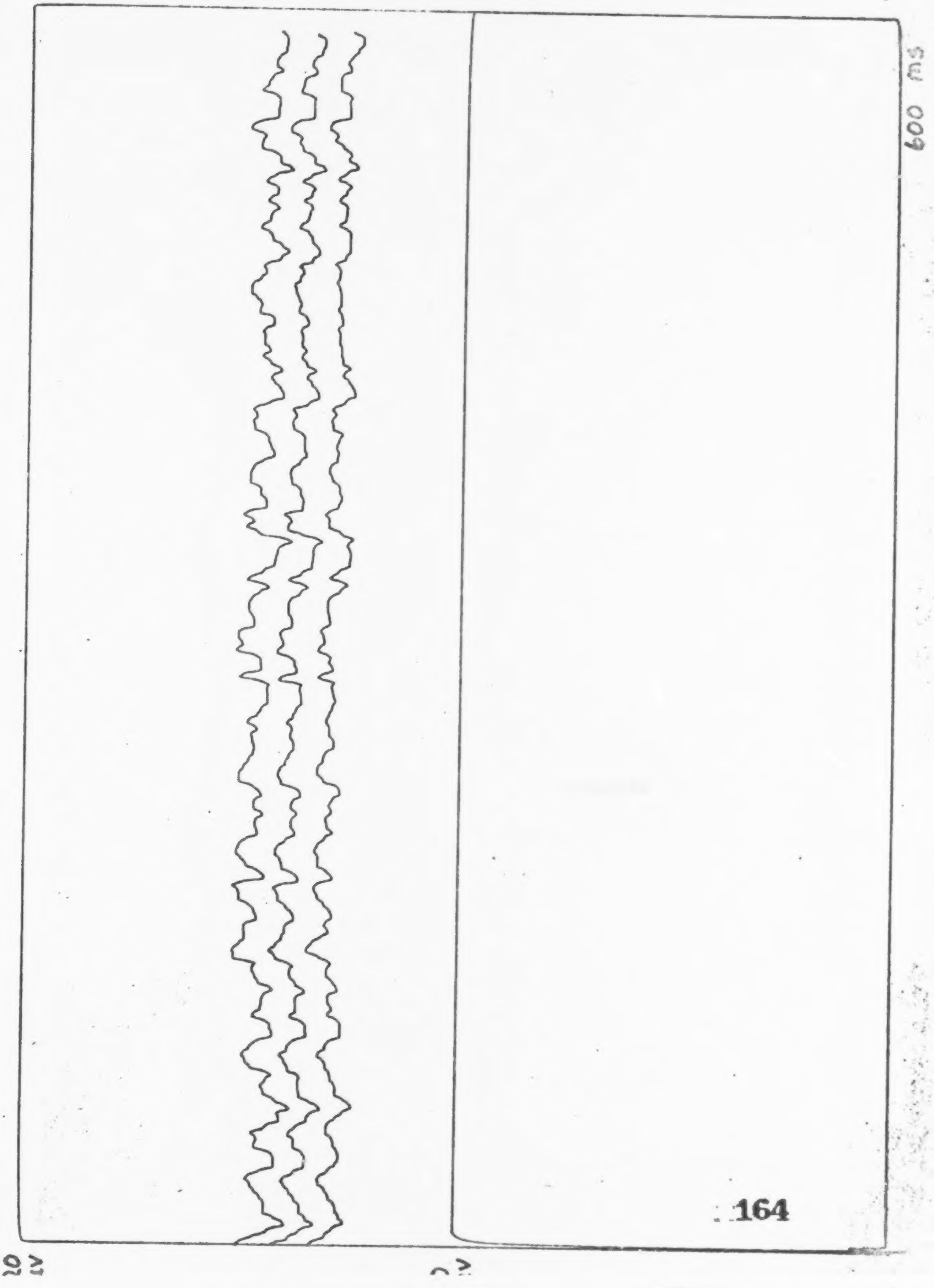
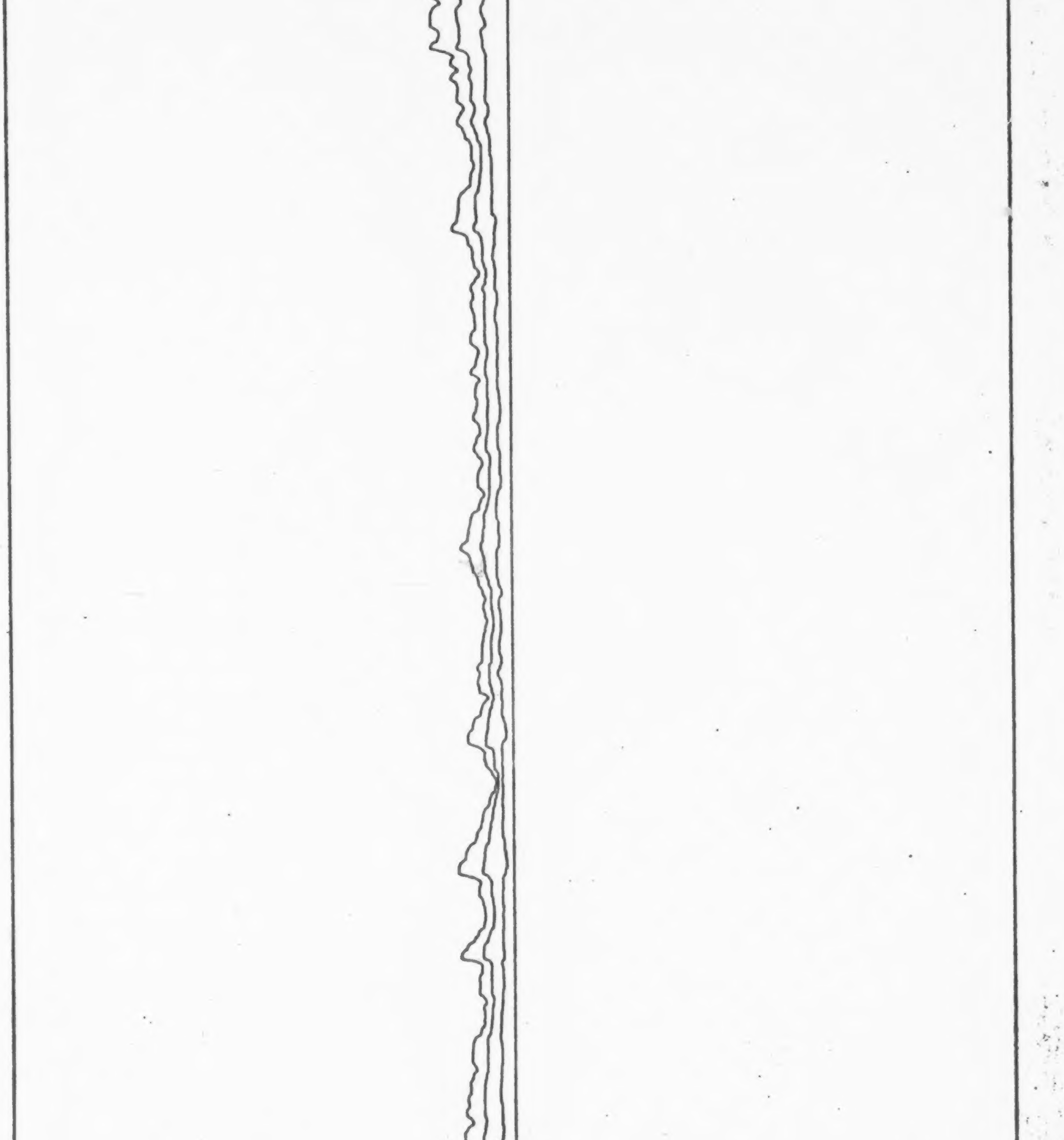

600 ms

Fig. 36. Average and 95% Confidence Limits of Lip EMG for Subject 2 for "Peep" During Listen-Repeat Condition


600 ms

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COVERT LINGUISTIC BEHAVIOR IN DEAF
SUBJECTS DURING THINKING

Abstract

Max's classical conclusion that covert finger movements occur in deaf subjects during thinking was tested using six subjects proficient in manual speech and who were learning oral speech. It was found that amplitude of left-arm and lip electromyograms (EMG) significantly increased during problem solving. Left-arm EMG increased significantly more during problem solving than during a nonverbal control task; integrated electroencephalograms (EEG) from the left motor area decreased significantly more during the former. No significant differences occurred for leg EMG, but respiration rate increased significantly during all tasks. In conformity with the findings of Max and Novikova, it was concluded that the manual and oral regions were covertly functioning as a single linguistic system during thinking.

COVERT LINGUISTIC BEHAVIOR IN DEAF SUBJECTS DURING THINKING

Following a motor theory of consciousness, Max (1937) hypothesized (among other things) that the activity of the linguistic mechanisms of deaf subjects would increase during the solution of "thought problems." His measure was electromyographic (EMG) activity of the musculature of both forearms that controlled finger movements (the locus of the subject's speech). A response was, implicitly, defined as any measureable voltage during problem solving; amplitude ranged .1-9 μv. He concluded that since

> abstract thought problems elicited action-current responses more frequently and to a greater extent in the arms than in the legs ... these manual responses in the deaf are more than adventitious effects of irradiated tensions ... and ... have some specific connection with the thinking process itself ... our results thus lend some support to the behavioristic form of the motor theory of consciousness [Max, 1937, pp. 336-337].

While Max's (1937) classical work on the waking thought processes received some confirmation from Novikova (1961) it has not yet been subjected to stringent replication by contemporary standards. It was, therefore, the purpose of this study, using certain methodological improvements, to test Max's conclusions on waking deaf subjects. In particular, an attempt was made to more adequately define a response increase, to improve on computational procedures, to use more sensitive recording and quantification equipment, and most important to simultaneously study activities at a variety of bodily locations.

Method

Subjects. Four congenitally deaf individuals and two who had been deaf since ages of 13 mo. and 4 yr. were brought to Hollins College from the two multiplication problems, two division problems, a nonverbal task, and a 10-min. reading period.[1] The nonverbal task was used as a control condition in which the subjects looked at a sheet containing the configuration of nonsense symbols used by Hull (1920); the intent here was to study the subjects under a condition of active attention, but where concentration was on nonlinguistic stimuli. Event signals were placed on the magnetic tape of the recorder to indicate the start and end of each problem-solving period.

Results

The EMG and EEG amplitudes that were digitized for each second were averaged for each task period for each subject; base-line amplitudes in each pretask rest period were similarly computed. In short, there was a mean amplitude for each pretask and for each task period for each measure. To "correct" for individual differences in response range, the ratio presented by Lykken, Rose, Luther, and Maley (1966) was used. Briefly, this ratio is the response mean minus the subject's minimum response amplitude, the result divided by the difference between his maximum and minimum response amplitudes. The ratio thus varies between zero and one such that the larger the value, the greater the amplitude. Considering each measure separately, a ratio was computed for each rest period and for each task period, and the former was subtracted from the latter; this yielded a measure of response increase during each task over base-line level. Group means of these response increases

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[1] Max's (1937) sentence rearrangement tasks were given to the first subject, but they were beyond his capacity and therefore dropped for the remaining subjects. Similarly, the tongue electrodes used for the nondeaf subjects were eliminated for the deaf subjects because the first deaf subject appeared threatened by that placement (lip electrodes were favored).

TABLE 1

MEAN RESPONSE-RATIO INCREASES OVER BASE LINE FOR THREE TASKS

Measure	Silent reading	Arithmetic	Nonsense symbols
Left-arm EMG	.13	.24*	.06
Right-arm EMG	.12	.11	.14
Lip EMG	.09	.10*	.12
Leg EMG	.00	.05	−.05
EEG	−.08	−.08	−.01

* $p < .05$.

based on all deaf subjects were then computed for the three kinds of tasks and are presented in Table 1 (a mean increase for the six arithmetic problems was first computed for each subject). It can be seen, for instance, that response amplitude in the left arm increased from resting (base-line level) to reading by a value of .13, that it increased during the arithmetic tasks by .24, and that the increase while viewing the nonsense symbols was .06. The means of Table 1 were tested to determine whether they were significantly different from zero (α was set at .05 throughout), and it was found that the only significant response increases occurred in the case of the left arm ($\underline{A}$ = .239) and lips ($\underline{A}$ = .209) during the solution of arithmetic problems; the left-arm increase during silent reading would have been significant at the .06 level ($\underline{A}$ = .304).

To determine whether any response increases during reading or during the arithmetic tasks were significantly different from increases during the control task of viewing nonsense symbols, differences between respective pairs of means were tested. Only the arithmetic tasks produced significantly greater changes than did the nonsense symbol task: The left-arm increase of .24 was significantly greater than .06 ($\underline{A}$ = .273) and the EEG decrease of -.08 was significantly different from -.01 ($\underline{A}$ = .277).

Respiration was quantified by computing both rate and maximum amplitude during the performance of each task, and during each corresponding pretask resting period; mean differences were then tested to determine whether they were significantly different from zero. Amplitude changes from resting to each of the three task conditions were all minor and none approached significance. However, respiration rate significantly increased for all three conditions. That is, number of respirations per minute increased from rest to silent reading by 4.3 ($\underline{A}$ = .206), from rest to problem solving by 4.9 ($\underline{A}$ = .176), and from rest to viewing nonsense symbols by 3.8 ($\underline{A}$ = .235).

A tests between these means considered pairwise indicate that they do not significantly differ.

Only small and nonsignificant changes in the ratios for arm amplitude occurred for the nondeaf subjects during the arithmetic and nonsense symbol tasks, the values varying .04 - .08. Similarly, leg amplitude did not noticeably increase from rest to the task conditions, the ratios varying -.21 -.05. In contrast, however, covert oral behavior noticeably increased during the two linguistic tasks, but not during the nonlinguistic one, viz., the increase for tongue EMG was .19 during reading ($A = .503$, $p < .05$), .19 during problem solving ($A = .501$, $p < .05$), and .09 while observing nonsense symbols ($A = .650$, $p > .05$).

Discussion

For the deaf subjects, the findings on left-arm EMG may be summarized as follows: (a) There was a significant increase during problem solving (with an increase of "borderline significance" during silent reading); (b) arm EMG did not significantly increase during the control task of viewing nonsense symbols; and (c) the increase during the arithmetic task was significantly greater than during the control task. Since little change occurred in the nonoral region sampled (viz., the leg), the arm increases during problem solving were probably not merely aspects of a heightened state of general bodily arousal, the same conclusion reached by Max (1937). These results are consistent with the interpretation that the finger and arm musculature were indeed covertly functioning as linguistic mechanisms during problem solving.

The significant increase in lip EMG during problem solving suggests that the oral region of these deaf subjects who were learning oral speech was also participating in the covert linguistic processes. This interpretation is in line with the findings of Novikova (1961) that both tongue and hand EMG increase during arithmetical operations in subjects proficient in oral and manual speech. Novikova concluded that in such subjects (both normal and deaf) there has developed a single functional system within the motor speech analyzer. Further evidence for such a single system came from Novikova's finding that hand EMGs of deafs increased during oral speech too, a finding also reported by Max (1937). In conformity with Novikova's work are the observations offered to us[2] that orally proficient deaf individuals often "mouth" words as they manually communicate them, and that during reception they focus on the face of others for lip reading (which stimulation may evoke oral behavior in the receiver).

Interpretations of the meaning of a difference between deaf and non-deaf subjects on any one characteristic, such as relative amplitude of arm EMG during thinking, is necessarily ambiguous, due to the confounds resulting from the large number of other differences between these two kinds of subjects. Furthermore, while we might expect covert arm activity of deaf subjects to be relatively great, this does not mean that the arms of normals are quiescent during problem solving (e.g., Davis, 1939). Nevertheless, the finding that amplitude of arm EMG in deaf subjects during problem solving was sizably elevated, in contrast to the smaller increases for subjects with normal hearing, is consistent with the interpretation that the linguistic mechanism is concentrated in the arms and fingers of deaf subjects.

These findings thus suggest that the manual and oral linguistic regions of our deaf subjects were covertly active during the thought processes, a conclusion consistent with that of Max (1937) and of Novikova (1961). There are, of course, other data that conflict with this interpretation, and the broad issue of how the various bodily systems function during internal information processing is far from settled. One counter example, for instance, is the conclusion of Smith, Brown, Toman, and Goodman (1947) to the effect that curarization of the musculature does not affect "consciousness." For further discussion of the conclusion of Smith et al. (1947) see McGuigan (1966, pp. 219-220); additional contrary data and statements are also included in McGuigan (1966).

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[2] John S. Shipman of the Virginia School for the Deaf and Blind, personal communication, July 28, 1970.

While the arms of the deaf subjects were covertly quite active during the problem-solving tasks, it is unclear as to why the left (nonpreferred) arm was the more active, since deaf subjects use their preferred arm more frequently in communicating. Max (1937) reported the same finding; introspective reports indicated to him that the left arm participated importantly in the solution of arithmetic problems, but this still doesn't explain its relatively greater activity. Might there be an unusual cerebral dominance, or unusual location of speech regions in the right hemisphere of deaf individuals? Simultaneous and extensive EEG study of both hemispheres might shed light on this question.

Since EEG amplitude decreases during alertness, the finding that integrated EEG was significantly lower while viewing nonsense symbols than during problem solving suggests that the brain was relatively more active under the latter condition.

The increases in respiration rate during all three tasks accords with previous results on hearing subjects, viz., that this measure increases during linguistic as well as during nonlinguistic activities. The relatively smaller increase during the control task is consistent with previous findings that linguistic activities lead to significantly greater increases than do nonlinguistic activities (McGuigan, 1970; McGuigan & Bailey, 1969).

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ELECTRICAL MEASUREMENTS OF NEUROMUSCULAR STATES DURING MENTAL ACTIVITY IV.

In a series of classic studies, Jacobson (1930, 1930a, 1930b, 1930c, 1931, 1931a, 1931b) investigated electrical activity in the skeletal musculature during the performance of a variety of mental activities. Using subjects who had been trained in progressive relaxation (Jacobson, 1925, 1938) (and also some who had not been so trained) Jacobson systematically studied changes in the voltage of covert electromyographic (EMG) responses following the hearing of such instructions as, "When the signal comes, imagine bending the right forearm." The results are generally accepted as a real and consistent effect in the direction of the experimental instructions. Control instructions indicated that the response was localized in the area in which the imagined muscular activity would have taken place, had the activity actually been carried out.

Jacobson (1932) took pains to point out the differences which exist between this covert electromyographic movement and the galvanic skin reflex (GSR). Among the differences he noted were the greater voltages of GSR readings as opposed to the much smaller voltages obtained in EMGs, the latencies of from 1.0 to 4.0 sec. obtained with GSR as contrasted with the fraction of a second which commonly intervened between signal and elongation of the EMG, as well as the differences in frequency, wave form, direction of potential, and tissue of origin of GSR vs. MAPs.

The present study was conducted as a replication of Jacobson's (1930, 1930a, 1930b, 1931b) work, though there were some differences in methodology. In this investigation, six sites were chosen from which electromyograms were simultaneously taken.

Method

Subjects. Fourteen right-handed female undergraduates at Hollins College volunteered to serve as subjects. All were naive as to the purpose of the experiment and all had normal or corrected vision. Ten served under a normal-awake condition and four while hypnotized.

Apparatus. The electromyographic recordings were taken by means of Grass (E 5 GH) gold cup electrodes. The signals from each pair of these electrodes were amplified by two Tektronix (Type 122) low-level preamplifiers in series, followed by a Honeywell (Model T 6 GA-600) galvanometer amplifier. The overall gain of this system was 10,000. All responses were recorded using a Sanborn (3907) seven-channel tape recorder.

All relaxation and imagination instructions were tape recorded and played at constant volume for each subject. The signal which alerted the subject to the onset and termination of test periods was generated by an Eico (Model 706) code oscillator at constant pitch.

Procedure. The subjects were seated comfortably in a reclining chair and fitted (after Davis, 1959) with six pairs of electrodes on the following surface locations: (1) a standard leg placement on the calf of the right leg, (2) a pair of longitudinal forearm flexor placements on both the right and left arms, (3) a pair of electrodes to detect lip musculature activity; one electrode was placed on the upper left portion of the lip, while the other was attached to the bottom right lip area, (4) one set of electrodes to record tongue musculature activity. These were brass caps, 4 mm. in height and 6 mm. in inside diameter, which were secured to the tongue by suction, and (5) electrodes placed at the external canthus of each eye. A gold cup grounding electrode was placed on the dorsal surface of the right hand.

When the subject had been prepared, the level of illumination in the subject chamber was dimmed, and the tape recorded instructions were begun. The tape recorded instructions were presented in the following sequence: outlining the task with an example ("Imagine sweeping the room with a broom") and then relaxing the subject for about three minutes. One minute of total silence intervened between the end of the relaxation instructions and the beginning of the first imagination instruction during which the subject could relax completely. This procedure represented an effort to stabilize the baseline. Though not specifically instructed to do so, the subjects kept their eyes closed throughout the experimental session.

The instructions (see Table 1) were chosen so that there were three questions in each of seven areas: speech (Sp), both arms (BA), vision (Vis), leg (Leg), arm (Arm), preferred arm (PA), and control (Con).

The order of presentation in Table 1 represented a randomization of three instructions from each of the seven areas. The imagination tasks were somewhat updated from Jacobson's earlier versions. Each task was presented, a two sec. imagination period followed, and the tone was then sounded. The tone signalled the subject to stop imagining and to relax again. In order that the subject did not develop an orienting reflex to the next instruction, the period of time between the offset of the tone and the onset of the following imagination instruction was varied between 13 and 17 sec.

Quantification Procedures

The tape-recorded data were reduced using a Digital Equipment Corporation LAB-8 computer. The four-channel analog-to-digital converter (ADC) associated with the computer was designed to accept signals having amplitudes from -1.00 + 1.00 v. With the aid of a program written in FOCAL programming language, the ADC was able to sample signals from the tape recorder at a rate of approximately 50 times per second. Because of these restrictions at the input of the ADC, it was necessary to apply some signal conditioning prior to the analog-to-digital conversion. The signals from the tape recorder were first amplified and full-wave rectified; this latter step was taken since it was felt that positive-going and negative-going electromyographic

Table 1

Imagination Instructions

1. Imagine multiplying 11 by 14. (Sp)
2. Imagine hanging onto a cliff with both arms. You're hanging on for your life. (BA)
3. Imagine a rocket ship blasting off. (Vis)
4. Imagine having to make a sudden stop in a car. (Leg)
5. Imagine bending the left arm. (Arm)
6. Imagine hammering a nail into a piece of wood. (PA)
7. Imagine that your left arm is perfectly relaxed. (Con)
8. Imagine bending your right arm. (Arm)
9. Imagine writing your name. (PA)
10. Imagine looking at the Eiffel Tower. (Vis)
11. Imagine peddling a bicycle. (Leg)
12. Imagine rowing a boat. (BA)
13. Imagine stating the date. (Sp)
14. Imagine your right arm is paralyzed. (Con)
15. Imagine watching a car speed by. (Vis)
16. Imagine lifting a 10 pound weight with your right arm. (Arm)
17. Imagine chinning yourself on a horizontal bar. (BA)
18. This time, don't bother to imagine anything at all. (Con)
19.[*] Imagine lifting a glass of milk to your mouth. (PA)
20. Think of the meaning of "incongruous." (Sp)
21. Imagine kicking a football. (Leg)

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[*] No. 19 was eliminated for the Hypnotized subjects.

signals should be treated as being equally indicative of muscular activity. The resulting signal was then passed through a resistor-capacitor (R-C) integrator with a time-constant of 20 msec.; this integrator was used to store details of the signal which were too rapid for the ADC to sample. The rectified and integrated signal was then passed into one channel of the ADC. Another A-to-D channel was used to detect a previously recorded timing pulse, which signalled the beginning of the experimental period.

The experimental data were taken as follows: at the beginning of the experimental period, the computer received a timing pulse from the tape recorder and began sampling the incoming data signal; the numbers representing the data were stored in the computer memory. At the end of the experimental period, sampling was halted and a numerical integration using the trapezoid rule was performed on the data. The integral of the signal was divided by the two-second time interval to furnish an average value of the muscular activity which was then printed out in μv. The control microvoltages were obtained in much the same way; the electromyographic signals were sampled in this case two to four sec. before onset of the instruction to assure that the subject was completely relaxed. The time period between sampling offset and instruction onset was varied in a random fashion. Thus, the sampling paradigm was one of a two sec. control period, followed by a short random period (zero to two sec.) Thereupon, an imagination instruction was presented with a two sec. imagination interval and a tone. In this manner, a two sec. control period was matched with every two sec. imagination period.

The data signals from the tape recorder were of varying maximum amplitudes, which characteristic necessitated variable gain in the data-reduction system. The output signals from the tape recorder were divided by the appropriate gain factors to yield equivalent microvoltages at the subject. A calibrated attenuator in the signal-conditioning system was then varied to give maximum scale factors of 15, 30, and 60 μv. for the electromyographic signals and 300 μv. for the eye signals. Calibration was performed as follows: with the data-reduction system set at 15 μv. full-scale, a 100 mv., 1000 Hz sinusoidal signal (equivalent to 10 μv. at the subject), generated by a Hewlett-Packard (Model 208A) test oscillator, was fed into the input of the system. This signal was chosen well above the cutoff of the R-C integrator in order to provide a DC signal at the input of the ADC. A variable attenuator in the signal conditioning system was then adjusted until the computer program indicated a value of 10 μv. Further adjustments in overall gain were performed only with the calibrated attenuator; the calibration was checked frequently during the data-reduction process.

Additional performance checks were made on the data-reduction system. In order to ascertain a level of tape recorder noise, the recording inputs of the seven-channel tape recorder were short-circuited and the instrument was placed in the record mode over an unused portion of the data tape. The computer program was then allowed to examine this blank portion of tape for each of the six data channels, using the appropriate gain factor for a given channel. The microvoltages thus obtained represented the noise level in the data-reduction system and were found to be quite constant in time (See Table 2).

This suggested that the playback signal could be treated as a physiological signal plus a constant noise level. For this reason, the noise figures were subtracted from the integrated averages by the computer prior to printout. Further tests of reproducibility performed during the data-reduction process indicated that the averaged muscular activity was replicable within approximately ± 7%.

In this manner, an experimental and control microvoltage was calculated for each of 21 instructions using six electrophysiological measures across

Table 2

Noise Levels within the Data-reduction System

Channel:	Offset in µv.
1. Right Leg	2.2
2. Right Arm	1.8
3. Lips	1.1
4. Tongue	1.3
5. Left Arm	2.2
6. Horizontal Eye	3.6

subjects. These were transferred onto data sheets divided on the basis of seven categories (See Table 2).

A mean relative difference was computed for each subject and for each instruction by adding each subject's experimental and control microvoltage value and dividing the sum by two; the absolute difference between experimental and control values was then taken and this difference was divided by the former figure giving a relative difference. This relative difference was then statistically tested by the A test.

Results

Group means for the 10 awake subjects are entered in Table 3, such that the higher the value, the greater the response amplitude during the imagination period. All but 27 differences (exclusive of the control category) were positive indicating that the mean experimental microvoltage was greater than the mean control microvoltage. Only in the case of instruction nine, right arm category, was there no difference between mean microvoltages. A tests were computed on the basis of these 10 subjects for the Awake Condition, grouped by instruction for each electrophysiological measure. The results of the A tests are shown in Table 4 (d.f. = 9). Only 11 out of the 126 A tests were statistically significant at the .05 level, which is about chance. Viewed as a whole, these results indicate lack of success in confirming the findings of Jacobson. One obviously crucial reason was that Jacobson used subjects whom he had trained to relax over a long period, whereas our subjects had no such training in progressive relaxation. One possible solution was to rapidly relax our subjects by means of hypnotism. Consequently, the experiment was repeated using four college students who imagined under hypnosis. The results, following the methods used for Table 3, are presented in Table 5. While there were too few subjects to consider running statistical tests, the mean results were more in line with those of

Table 3

Mean Differences Between Experimental and Control Microvoltages for 10 Awake Subjects. Response Means to Non-Target Tasks Appear in Parenthesis

Category		Response Measure					
		Leg	Right Arm	Lips	Tongue	Left Arm	Horizontal Eye
Speech Instruction	1	.33	.17	.15*	.22	.14	.06
	13	.24	-.05	.04	.35*	.29	.35
	20	.16	.06	.18	-.15	-.02	.17
	X̄	.24(.16)	.06 (.10)	.12(.01)	.14(-.10)	.14(.27)	.19 (-.08)
Arms Instruction	2	.21	.34	.10	.12	.30	-.12
	12	.13	.05	-.02	-.15	.28	-.52*
	17	.16	.14	.20*	.10	.25	-.05
	X̄	.17(.17)	.18 (.08)	.09(.17)	.02 (.12)	.28(.25)	-.23 (.00)
Vision Instruction	3	.15	.24	.12	-.08	.24	-.04
	10	.20	.01	.15	.18	.17	.20
	15	.21	.10	-.02	-.03	.32	-.13
	X̄	.19(.17)	.12 (.10)	.08(.02)	.02 (.12)	.24(.26)	.01 (-.04)
Right Leg Instruction	4	.28	.12	.43	.38*	.38	-.01
	11	.21	-.22	.03	.06	.28	.22
	21	.33	.07	.06	.30	.56	-.21
	X̄	.27(.16)	-.01 (.12)	.17(.00)	.25 (.08)	.41(.23)	-.00 (-.04)
Non-Preferred Arm Instruction	5	-.30	.05	-.02	.13	.12	-.04
	8	-.10	.20	-.20	.10	.30	-.01
	16	.21	.30*	.08	.29*	.29	-.28
	X̄	-.06(.21)	.18 (.08)	-.05(.04)	.17 (.10)	.24(.25)	-.11 (-.02)
Preferred Arm Instruction	6	.18	.12	.02	.06	.16	-.07
	9	.20	.00	-.21	.20	.30	-.24
	19	.20	.25	.06	.39*	.22	.10
	X̄	.19(.17)	.12 (.10)	-.04(.04)	.22 (.09)	.23(.26)	-.07 (-.03)
Control Instruction	7	.18	.03	-.25*	-.22	.17	-.01
	14	.20	.13*	-.04	.12	.28	-.20
	18	.25	-.04	-.24	-.08	.23	.13
	X̄	.21(.17)	.04(.11)	-.18(.06)	-.06 (.14)	.23(.26)	-.03 (-.04)

* $p < .05$

Table 4

Values of A Tests Computed on 21 Questions by Six Response Measures (Awake Subjects)

Category		Response Measures					
		Leg	Right Arm	Lips	Tongue	Left Arm	Horizontal Eye
Speech							
Instruction	1	.37	.41	.21*	.45	.66	18.99
	13	.73	3.96	1.45	.26*	.52	.45
	20	1.23	1.14	.62	4.18	135.78	1.36
Both Arms							
Instruction	2	.87	.36	.84	.96	.34	1.99
	12	3.90	1.93	13.43	2.39	.43	.25*
	17	.84	.35	.24*	2.61	.64	3.48
Vision							
Instruction	3	1.49	.47	1.28	1.82	.40	22.76
	10	.86	138.93	1.57	.33	.63	.98
	15	1.17	.49	6.64	25.72	.45	1.25
Right Leg							
Instruction	4	.63	.55	.38	.27*	.33	221.60
	11	.85	.89	15.64	9.25	.36	.75
	21	.52	1.29	1.70	.29	.28	.56
Arm							
Instruction	5	.63	3.47	32.07	.55	.60	16.27
	8	5.68	.19*	.89	2.51	.52	381.69
	16	1.25	.17*	.41	.23*	.51	.45
Preferred Arm							
Instruction	6	1.04	.50	10.54	1.99	.64	5.91
	9	.85	9,547.7	1.01	.91	.52	.34
	19	.91	.36	1.63	.22*	.69	2.34
Control							
Instruction	7	.87	16.94	.25*	.48	.47	660.09
	14	1.15	.22*	4.09	1.16	.59	.87
	18	.66	4.94	.95	6.20	.74	1.11

* $p < .05$

Table 5

Mean Differences Between Experimental and Control Microvoltages for 4 Hypnotized Subjects. Response Means to Non-Target Tasks Appear in Parenthesis

Category		Response Measure					
		Leg	Right Arm	Lips	Tongue	Left Arm	Horizontal Eye
Speech Instruction	1	1.6	0.3	2.6	6.6	0.4	-0.1
	13	0.5	-0.9	-0.1	0.6	0.2	-0.6
	20	-0.2	0.4	0.1	0.9	-0.5	-0.5
	X̄	0.6(-.12)	-0.1 (.68)	0.9 (.12)	2.7(-.05)	0.0 (.13)	-0.3 (.38)
Arms Instruction	2	0.0	1.8	0.8	6.8	0.4	0.2
	12	0.2	-0.4	-1.3	-1.4	0.2	-0.3
	17	-0.4	1.6	0.6	-1.9	-0.1	0.5
	X̄	-0.1(.00)	1.0 (.50)	0.0 (.27)	1.2 (.20)	0.2 (.10)	0.1(-.45)
Vision Instruction	3	0.5	-1.2	-1.2	2.6	0.1	-1.4
	10	-1.0	-0.7	-1.3	-4.5	0.3	-1.0
	15	0.3	1.8	-1.0	0.3	0.3	1.3
	X̄	-0.1(.00)	0.0 (.67)	-1.2 (.47)	-0.5 (.48)	0.2 (.10)	-0.4(-.37)
Right Leg Instruction	4	0.4	0.9	2.6	3.6	0.1	-0.8
	11	0.4	0.7	0.3	1.6	0.5	-0.3
	21	0.5	0.3	-1.8	-1.1	0.0	-0.6
	X̄	0.4(-.01)	0.6 (.57)	0.4 (.20)	1.4 (.17)	0.2 (.10)	-0.6(-.33)
Non-Pefer-red Arm Instruction	5	0.4	0.7	1.2	0.7	0.4	-0.1
	8	-0.1	2.4	1.1	-1.5	0.0	-0.4
	16	-0.4	1.1	0.3	-1.6	0.5	-0.5
	X̄	0.0(.00)	1.4 (.43)	0.9 (.12)	-0.3 (.53)	0.3 (.08)	-0.3(-.38)
Preferred Arm Instruction	6	0.4	-0.6	1.1	0.7	-0.4	-0.3
	9	-1.4	2.5	0.8	-1.4	0.4	-1.2
	X̄	-0.5(.01)	1.0 (.50)	1.0 (.10)	-0.4 (.47)	0.0 (.13)	-0.8(-.30)
Control Instruction	7	0.0	-1.5	0.2	-1.4	0.1	-0.2
	14	-0.7	0.[illegible]	-1.8	-1.8	-0.3	-0.2
	18	0.5	1.0	0.3	-0.5	-0.2	-0.4
	X̄	-0.4(.05)	0.1 (.65)	-0.4 (.33)	-1.2 (.60)	-0.1 (.15)	-0.3 (.38)

Jacobson. Figures 1 and 2 illustrate the findings more clearly than do the tables. In Figure 1 we have plotted the mean amplitude values from Table 3 for the measure particularly involved with each task. Then, for comparison purposes, we have plotted the mean value of that measure for all other tasks. For example, the lips and the tongue should be intimately involved for the Speech Category of imagination tasks. We can see that the lip and tongue values for the awake subjects are in fact somewhat higher for the critical tasks than for the other tasks, but the effect in general is quite small. In contrast, Figure 2 shows that the relevant measures for the target tasks reacted much more in conformity with expectations, based on Jacobson's data. Hence, for speech tasks, the lips and tongue are dramatically more active than for the other tasks. When both arms were supposed to be used, the mean activity for both arms also was relatively high. The effect was not so pronounced for vision (negative values indicate as much activity as do positive values in the case of the eye). The leg and arm regions did respond appropriately, though.

In conclusion, then, it seems that the effect reported by Jacobson did appear in our hypnotized subjects. This may have been because they were well relaxed through suggestion, but any general hypnotic effect cannot be discounted either. Ideally, the experiment should be reported after the subjects went through Jacobson's progressive relaxation training.

Figure Caption

Figure 1. Response Amplitudes for Target and Non-Target Tasks for Awake Subjects.

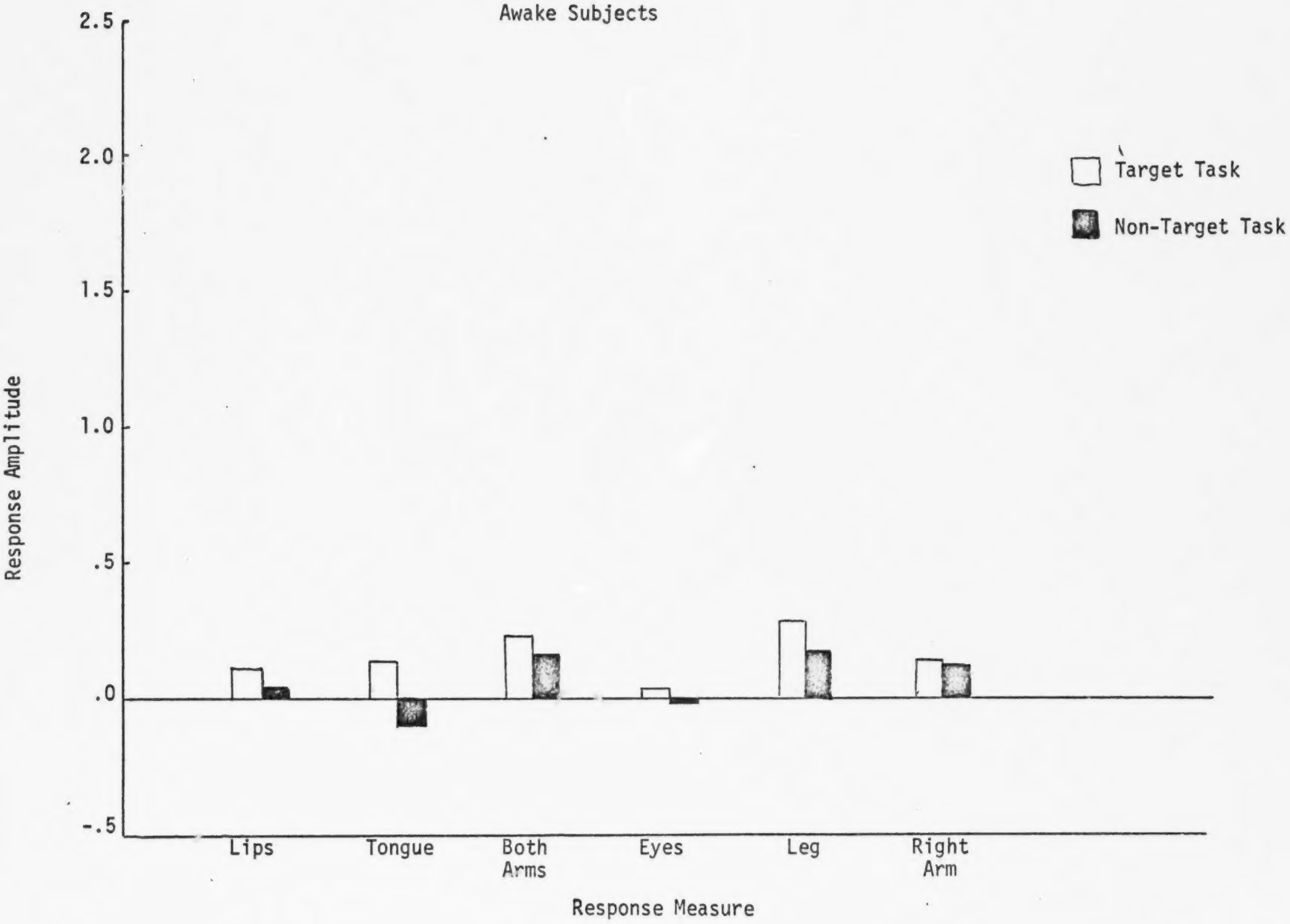
Awake Subjects
2.5
2.0
1.5
1.0
.5
.0
-.5
Response Amplitude
Target Task
Non-Target Task
Lips
Tongue
Both Arms
Eyes
Leg
Right Arm
Response Measure

Figure 1

Figure Caption

Figure 2. Response Amplitudes for Target and Non-Target Tasks for Hypnotized Subjects.

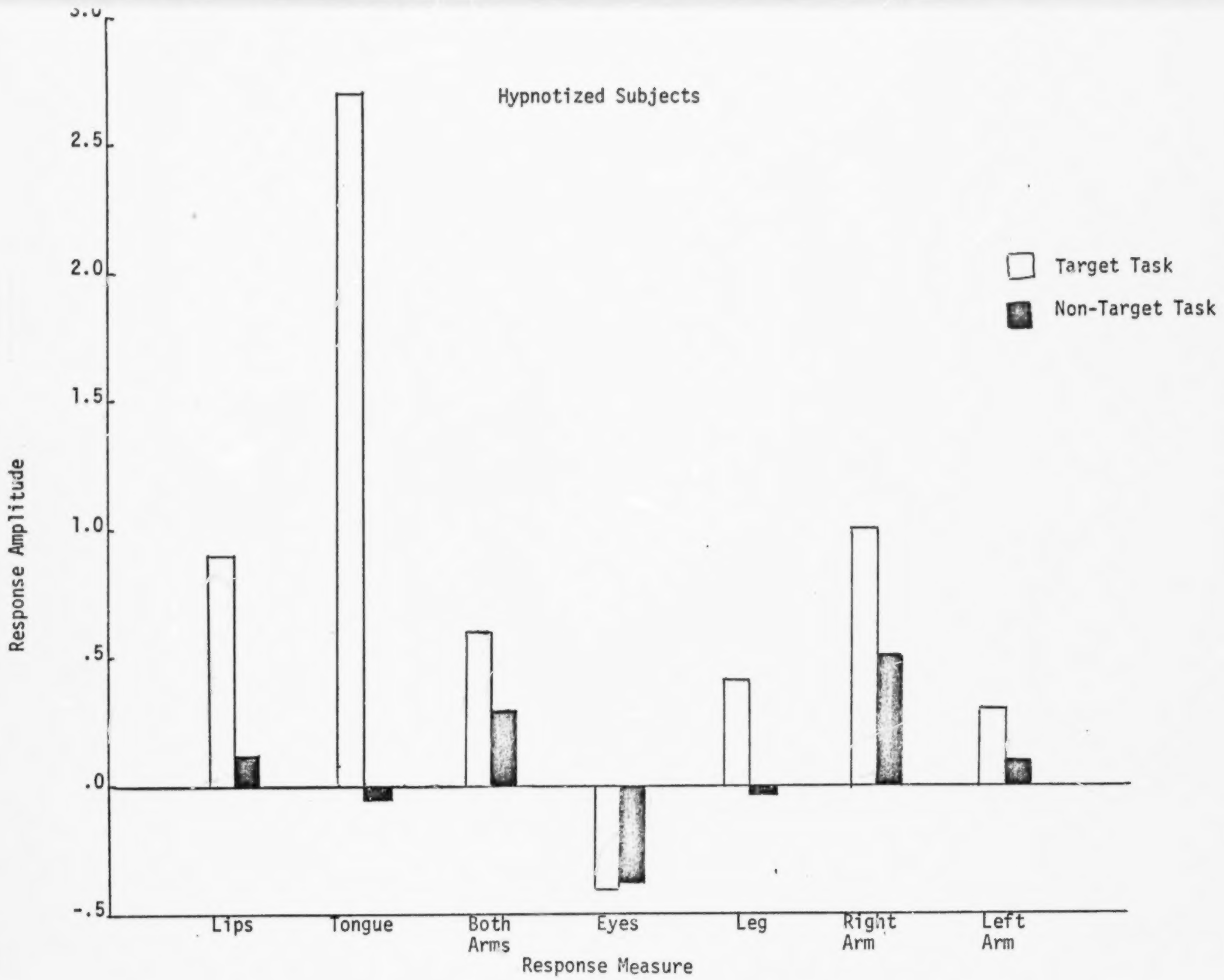
Hypnotized Subjects
Target Task
Non-Target Task
Response Amplitude
3.0
2.5
2.0
1.5
1.0
.5
.0
-.5
Lips
Tongue
Both Arms
Eyes
Leg
Right Arm
Left Arm
Response Measure

Figure 2

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COVERT ORAL BEHAVIOR DURING CONVERSATIONAL AND VISUAL DREAMS

Abstract

Previous findings of heightened covert oral behavior during linguistic activities suggested that increases in covert oral behavior might also occur during conversational dreams. It was found that covert oral behavior (lip and chin electromyograms) was significantly higher during rapid eye movement (REM) periods in which there were conversational dreams than during nonrapid eye movement (NREM) periods. On the other hand, REM periods for the visual dreams showed only minor and nonsignificant changes in covert oral behavior, relative to the NREM periods. Little change occurred for neck responses, suggesting that behavioral changes were localized in the speech region. These findings are thus consistent with those obtained from waking subjects -- covert oral behavior may serve a linguistic function during dreams too.

COVERT ORAL BEHAVIOR DURING CONVERSATIONAL AND VISUAL DREAMS

Heightened covert oral behavior, as measured by electromyograms (EMG) from speech muscles, occurs during the performance of a wide variety of linguistic activities (auditory hallucinations, silent reading, writing, thinking, etc.), indicating that the covert oral response may function to facilitate internal information processing (McGuigan, 1970). An extension of these findings suggests that covert oral behavior should also be apparent during dreams which involve language. It was, therefore, predicted that there would be a noticeable increase in amplitude of covert oral behavior during conversational dreams but not visual (nonlinguistic) dreams.

Method

The subjects were four female undergraduates at Hollins College. Each slept in the laboratory for four consecutive nights and was paid $5.00 a night. The subject and apparatus rooms contained effective shielding for extraneous signals. EMGs were continuously recorded during sleep from the chin, lips, and neck, as were frontal electroencephalograms (EEG), and eye movements from the external canthi, all recorded on a seven-track data tape recorder. The signals were visually monitored by oscilloscopes throughout each night, and the subject was awakened after each rapid eye movement (REM) period. At that time the subject's dream report was recorded on an audio tape recorder, and the subject gave a clarity rating of the dream using the method of Roffwarg, Dement, and Muzio (1962). Those dreams that received the subject's highest clarity rating (viz., 3) were later classified for type of content; for this, three independent judges used a 5-point scale that ranged from "primarily visual content" to "primarily conversational content." Dreams judged by all three raters to be "primarily visual" or "mostly visual" were classified as "visual dreams," while those dreams which were unanimously judged to be "primarily conversational" or "mostly conversational" were classified as "conversational dreams." Recorded data were analyzed for these REM periods; "nonrapid eye movement" (NREM) comparison data were selected for an equal period of time from a point terminating 5 min. prior to the onset of each REM period.

Results

A total of 25 dreams received the high clarity rating. Thirteen of these met the independent rater criteria: eight were classified as visual and five as conversational dreams. All psychophysiological signals were integrated, digitized, and amplitudes were printed out for each REM period and for each preceding NREM period (for details, see McGuigan, 1967). Mean amplitudes for each REM and corresponding NREM period were then computed for each measure, and the latter was subtracted from the former. A mean response increase from the NREM to the REM periods was then computed for each subject's visual and conversational dreams. Group means of the NREM and REM periods and their differences are presented in Table 1. It can be seen that both of the covert oral measures significantly increased from the NREM to the REM periods during conversational dreams (A = .282 and A = .307 for lip and chin EMG, respectively). In contrast, during visual dreams the differences for lip and chin EMG were minor and nonsignificant. The increases in lip and chin EMG during conversational dreams are noticeably larger than during visual dreams, but the differences in this case only approach significance (A = .440 and A = .401, respectively). No other differences in Table 1 are significant. The nature of these results is illustrated by the sample tracings in Figures 1, 2, and 3. The relatively quiescent lip and chin EMG during the NREM period (Fig. 1) and visual dream (Fig. 2) can be seen to increase phasically during the conversational dream (Fig. 3). The rather large, slow waves from the frontal EEG placement (reflecting both brain and eye activity) during this particular visual dream (Fig. 2) is noteworthy.

Table 1

Amplitude Changes (μV) of Psychophysiological Measures as a Function of Dream Content

	Type of Dream					
	Visual			Conversational		
Measure	NREM Period	REM Period	Diffe-rence	NREM Period	REM Period	Diffe-rence
Lip EMG	5.4	5.7	.3	5.1	7.0	1.9*
Chin EMG	8.8	8.6	—.2	7.9	10.7	2.8*
Neck EMG	29.3	29.1	—.2	24.9	25.0	.1
Horizontal Eye	43.0	50.6	7.6	51.7	61.3	9.6
Frontal EEG	4.2	5.1	.9	3.9	4.6	.8

*$p < .05$

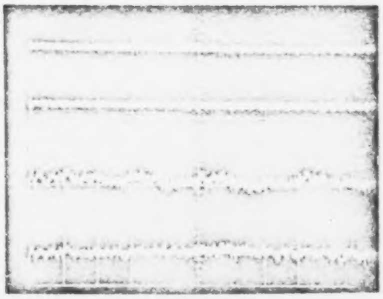

Fig. 1. Illustration of signals during NREM periods. Reading from top down, signals are lip EMG, chin EMG, from horizontal eye placement, and frontal EEG. Amplitude for the top three traces is 50 microV/division and 100 microV/division for EEG. Time is 1 sec/division.

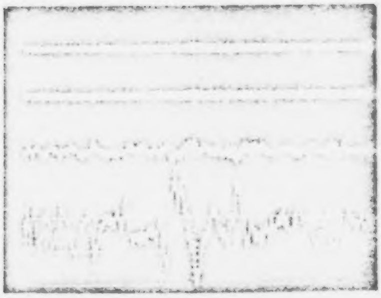

Fig. 2. Illustration of signals during a visual dream, as in Fig. 1.

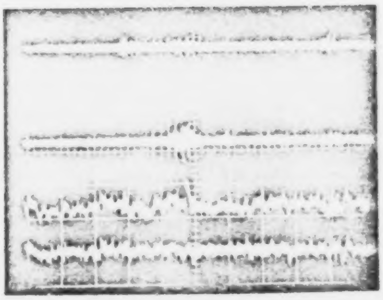

Fig. 3. Illustration of signals during a conversational dream, as in Fig. 1.

In conclusion, we may note that: (1) both measures of covert oral behavior significantly increased during conversational dreams relative to amplitudes during preceding NREM periods; (2) during visual dreams covert oral behavior did not significantly increase; and (3) amplitude changes from NREM to REM periods for neck EMG were minor and nonsignificant. These results suggest that dreams containing auditory speech content are associated with increases in covert oral behavior; since these increases did not appear in the nonoral region sampled (viz., the neck), they seem to have been localized in the speech region. These findings are thus consistent with the hypothesis that covert oral response during dreaming, as in waking life, serves a linguistic function. Covert oral behavior may facilitate internal information processing during conversational dreams.

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THE FUNCTION OF COVERT ORAL BEHAVIOR ("Silent Speech") DURING SILENT READING

Abstract

The purpose was to summarize research relevant to the question as to whether heightened covert oral behavior ("subvocalization" or "silent speech") during silent reading is beneficial or detrimental to the reader. It was first concluded that covert oral responses do reliably occur during silent reading, but probably not during non-linguistic tasks and that they are probably localized in the speech region. To attempt to understand the function of covert oral behavior during silent reading, subject and environmental variables with which amplitude varies were specified. Previous research indicated that amplitude is inversely related to reading proficiency for selected subjects, but increases when proficiency is experimentally increased. Experimental decreases of covert oral behavior seem to reduce reading proficiency. Amplitude also increases as textual and environmental demands increase. It was concluded that the covert oral response facilitates reading proficiency. Perhaps the visually-received text evokes conditional speech muscle activity that generates a verbal code. The code, it is hypothesized, is neurally transmitted to the brain to facilitate integration of the various central language regions.

THE FUNCTION OF COVERT ORAL BEHAVIOR ("SILENT SPEECH") DURING SILENT READING

Typically, educators have held that "subvocalization" during silent reading is detrimental to reading proficiency, e.g., Betts (1950) has stated that "...any observable form of vocalization -- such as silent lip movement...retards the rate of silent reading (which) has been common professional knowledge since the early scientific studies of reading" (p. 450). In contrast to this widespread view of the function of covert oral behavior, Schilling (1929) concluded on the basis of his research that "Motor expression of speech movements favours the understanding of what is read. Suppression inhibits the understanding of what is read" (p. 223). More recently, Edfeldt (1960) concluded that it is likely that "...silent speech actually constitutes an aid toward better reading comprehension" (p. 154). It is the present purpose to attempt to decide between these conflicting hypotheses by summarizing and interpreting directly relevant results of research. First, we should determine whether or not the covert oral response does reliably occur during silent reading; the next step would be to see how and under what conditions it changes -- by specifying the environmental and subject variables of which covert oral behavior is a function, we should gain some insight into whether it is detrimental or beneficial during silent reading.

Measurement of Covert Oral Behavior

While speculations about the function of "inner speech" and the like are, literally, ancient (cf. Langfeld, 1933), Curtis (1900) made the first effort to directly record the covert oral response. The early studies that followed, concluding with the work of Thorson (1925), used mechanical techniques for measuring behavior, necessarily so crude that one is surprised when researchers thought they had obtained positive evidence of such miniscule events as covert responses. These mechanical techniques were replaced by the extremely sensitive procedures of electromyography, pioneered by Jacobson in 1927. Apparently, the first electromyographic (EMG) measures of covert oral behavior during silent reading were made by Faaborg-Anderson and Edfeldt (1958), though Jacobson and Kraft in 1942 had studied a non-oral measure (leg EMG) during silent reading. Faaborg-Andersen and Edfeldt (using needle electrodes) concluded that the silent speech of adults during silent reading specifically involved an increase (from rest) in electrical activity in the vocal and mylohyoid muscles, but a decrease in the cricoarytenoid. Edfeldt (1960) recorded mylohyoid EMG from Swedish college subjects with needle electrodes and concluded "...that silent speech occurs in the reading of all persons" (p. 154). McGuigan, Keller and Stanton (1964) measured surface lip and chin EMG in children and college students, and found that covert oral behavior significantly increased over rest during silent reading in both kinds of subjects. Mean numbers of subvocalizations per minute (studied through high audio amplification) during silent reading for two samples of children were 1.53 and .43, but 0.00 for the college students. Respiration rate (possibly linked with covert oral behavior) also significantly increased during silent reading. In two experiments, McGuigan and Rodier (1968) confirmed previous findings of increased covert oral behavior (tongue and chin EMG), and increased respiration rate during silent reading, relative to rest. Sokolov (1969) reported increased speech muscle activity during a variety of linguistic tasks, including silent reading. During a task closely related to reading, viz., cursive writing, heightened covert oral behavior (tongue and chin EMG) occurred in college students; the increased behavior was relative to rest and also relative to amplitude during the performance of two non-linguistic comparison tasks (McGuigan, 1970). McGuigan and Bailey (1969a) found that college students significantly increased amplitude of chin and tongue EMG during silent reading (and also during memorization of prose) over baseline level, and that these increases were significantly greater than under two non-linguistic conditions (listening to music, and attentively listening to a blank tape on a tape recorder). Additionally, respiration rate and preferred arm EMG significantly increased during silent reading (these two measures also increased during two other linguistic conditions, viz., memorizing, and listening to prose); these increases were, furthermore, greater than under the two non-linguistic conditions of listening to music and to nothing. Finally increases in covert oral behavior during silent reading were not accompanied by increases in a sample of non-speech regions of the body (cf., McGuigan, 1970).

In summary, the above results indicate that covert oral behavior typically increases during silent reading, relative to a resting baseline condition. Additionally, there was some evidence that the increased level of covert oral responding during silent reading was greater than during a sample of non-linguistic tasks, and that that behavioral increase is localized in the speech region. In short, relatively localized covert responses seem to occur in the oral regions, and they seem to be uniquely associated with silent reading (and similar linguistic tasks); apparently this phenomenon is quite general among language proficient people (cf. McGuigan, 1970 for a summary of research on covert oral behavior during other linguistic tasks). We shall now consider the second step proposed in the introduction, viz., a specification of the variables of which amplitude of covert oral behavior is a function.

Systematic Changes in the Amplitude of Covert Oral Behavior

Two categories of variables will be considered--subject characteristics and environmental variables. Two sub-classes of the former will be changes in covert oral behavior as a function of characteristics as they are selected in subjects, and as a function of experimentally produced changes in subjects.

Subject Variables

The earliest EMG study of covert oral behavior during silent reading as a function of selected characteristics of subjects was by Faaborg-Andersen and Edfeldt (1958). These researchers selected Danish subjects who were accustomed to reading a foreign language (Swedish) and subjects who could read Swedish but were not accustomed to it. They found that silent speech (vocal and mylohyoid EMG) was substantially greater for those who were unaccustomed to reading the foreign language. Adults selected on the basis of their poor reading and writing proficiency emit larger amplitudes of covert oral behavior during silent reading and writing than do adults who are good readers and writers (Edfeldt, 1960; McGuigan, 1970). Similarly, more covert oral behavior occurs in children while reading than in adults, who were (obviously) the more proficient readers (McGuigan, et al., 1964; McGuigan & Pinkney, 1971). Furthermore, children selected on the basis of especially high levels of covert oral behavior while reading, naturally decreased their covert oral response amplitude over the years, as reading proficiency improved, but response amplitude stabilized at about the normal adult level (McGuigan & Bailey, 1969). Furthermore, audible subvocalizations were prominent in the first test but none were detected after three years. We may thus conclude that amplitude of covert oral behavior is inversely related to reading proficiency of selected subjects.

Two possible experimental strategies for deciding whether the covert oral response is beneficial or detrimental, are to: 1) increase reading proficiency and note any consequences on covert oral behavior, and 2) manipulate amplitude of covert oral behavior and note consequences on reading proficiency. If increased reading proficiency results in reduced amplitude of covert oral behavior, the theory that the response is detrimental would be supported; no change or an increase in response amplitude would suggest that the response is beneficial (strategy 1). By strategy 2, should reduction in response amplitude result in decreased reading proficiency, one could conclude that the response was beneficial; an increase in reading proficiency would suggest that the response is detrimental.

When adult reading rates were *experimentally* improved by 149 wpm (confirmed by systematic changes in electrically-measured eye movements) the amplitude of tongue EMG significantly increased; a similar increase in tongue EMG occurred in children, as a result of increased rate (increases of 172 wpm and 220 wpm in two experiments). But perhaps because amplitude of covert oral behavior for the children was relatively large at the start of the experiment, the effect was not as pronounced for the children as it was for the adults. Tongue EMG, incidentally, decreased for all three control groups in these three experiments (McGuigan & Pinkney, 1971). Similar results occurred in a remedial reading case (McGuigan & Shepperson, in press), i.e., a child's reading proficiency was increased from the 5.6 grade level to the 7.3 grade level, as measured by a standardized test. Tongue and chin EMG also sizeably increased from before to after the treatment. These apparent behavioral consequences of improving reading proficiency thus seem to be more consonant with the theory that covert oral behavior facilitates reading proficiency.

For the second strategy, external feedback techniques *have* successfully reduced amplitude of covert oral behavior during silent reading (cf., Hardyck, Petrinovich & Ellsworth, 1966; McGuigan, 1967; McGuigan, 1969; and Hardyck & Petrinovich, 1969). The only study in which reduced amplitude was shown to affect reading proficiency was that by Hardyck and Petrinovich (1970); these experimenters reduced laryngeal EMG (surface electrodes) through external feedback while college subjects read easy and difficult passages. Relative to two other groups who did not receive laryngeal feedback, Hardyck and Petrinovich found that "the laryngeal feedback group did significantly less well on comprehension of the difficult material," (p. 647), leading them to conclude that "...subvocal speech...is a useful stimulus input capable of mediating a cognitive response" (p. 651). Data reported by McGuigan (1971) indicate, though, that reduced amplitude of covert oral behavior is temporary and dependent on the presence of the feedback signal [though this empirical finding conflicts with the statements of Hardyck _et al_. (1966, 1969) that the reduction is rapidly accomplished and permanent.] In conclusion for the second strategy, reduced covert oral behavior seems to reduce reading proficiency; but due to the complexity of the methodological problems and to the crudeness of measures of reading proficiency as rate in words per minute and comprehension as a percentage, more extensive research on this matter has high priority.

In summary, the purposive manipulation of reading proficiency by increasing rate seems to increase amplitude of covert oral behavior, but in any event it does not decrease; furthermore, experimental reduction of response amplitude seems to decrease reading proficiency.

Environmental Variables.

As far as external stimulus variables are concerned, amplitude of covert oral behavior is increased by increasing the level of difficulty of the prose being read, and by increasing the blurriness of the letters (Edfeldt, 1960). While their subjects were silently reading, McGuigan and Rodier (1968) systematically introduced white noise, auditory prose different from that being read, and the auditory prose played backwards. They concluded that presentation of prose and of backward prose led to a significantly greater amplitude of covert oral behavior than while reading during silence, but noise did not have that effect. These results on environmental variables thus indicate that amplitude of covert oral behavior becomes exaggerated as the text and conditions become more demanding.

Discussion and Conclusion

In summary, the findings indicate that amplitude of covert oral behavior is inversely related to reading proficiency of selected subjects, and is a direct function of the degree of the textual and environmental demands. In experimental manipulation of reading rate and of amplitude of covert oral behavior, it seems that amplitude of covert oral behavior and reading proficiency are directly related. The following picture thus emerges. While reading, one orally responds to the words that constitute the prose being read. In first learning to read, the child necessarily makes large articulatory movements as he attempts to pronounce the written word. Like any motor skill, as proficiency increases, the gross amount of muscular activity becomes reduced and his efficiency increases--as one learns to read, swim, or ride a bicycle, initial large scale and erratic movements become woven into smooth, highly coordinated response chains. In reading, these response chains are most efficiently run off at the covert level. Hence, the covert oral response persists in the adult, and continues to function while reading, be it overt or silent. During silent reading, when conditions demand, the response increases in amplitude--presumably, the poor reader and the person reading under demanding conditions enhance the reading process by exaggerating their amplitude of covert oral behavior.

Similarly, by suddenly increasing one's reading rate, there are demands for increased amplitude of covert oral behavior; presumably, as one practices at the faster rate, amplitude of response will decrease, just as it naturally does with young children.

To briefly consider what is meant by "amplitude of covert oral behavior," we may note that muscle fibers obey the all or none law. Hence, as EMG amplitude increases, fibers _per se_ cannot increase in amplitude; rather, as they contract, they may fire more rapidly or the number firing per unit time may increase. Hence, where we conclude that increased amplitude of covert oral behavior facilitates silent reading, more precisely we should say that there is an increase in the rate with which oral muscle fibers are firing and/or there is an increase in the number firing per unit time. In either case, the increase seems to facilitate the reading process, a conclusion that is consonant with the more general interpretation that the covert oral response functions in internal information processing (McGuigan, 1970). It may be that speech muscle activity generates a verbal code that is carried to the brain, and as Sokolov (1969) has suggested, the afferent neural impulses may serve to help integrate the various linguistic regions of the brain. Consonant with a principle of behavioral efficiency, the accomplished reader typically generates a minimal amount of afferently carried verbal information in his oral region. But the poorer reader, or the good reader under distracting conditions, requires a greater amount of verbal information, perhaps needs to send a redundancy of information to his brain. The implication for the teacher, thus, is that she should not tamper with the child's subvocalization--it is likely that the child _needs_ to subvocalize while reading and, in any event, the subvocalization naturally becomes reduced in time.

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